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Masterstudiengang Biologie

MASTERARBEIT

Studies on the influence of temperature on the feeding rates of important mesograzers in the western Baltic Sea

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Oldenburg, 01. Juni 2015

„In der lebendigen Natur geschieht nichts, was nicht in der Verbindung mit dem Ganzen steht.“

(Johann Wolfgang von Goethe)

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III. Zusammenfassung

Der Klimawandel hat zahlreiche Studien hervorgerufen. Viele von ihnen beziehen sich auf Stressökologie. Die Temperatur gilt dabei als entscheidender Einflussfaktor. Es ist bekannt, dass „Keystone species“ in der Lage sind Lebensgemeinschaften und sogar Habitate strukturierend zu prägen. Mesograzer grasen nicht nur an Algen (top-down), sondern dienen auch als Nahrungsressource für kleinere Fische (bottom-up). Diese Arbeit beschäftigt sich mit dem Einfluss von Temperatur auf die Fraßraten zweier Mesograzer aus der Ostsee, *Gammarus* spp. und *Idotea* spp. Es wurde vermutet, dass die Fraßrate in einer Art Optimumskurve auftreten würde. Es wurden Fraßversuche mit Individuen beider Gattungen bei Temperaturen von 5°C bis 30°C durchgeführt. Als Futter wurden Algen-Pellets verwendet. Es wurde eine Temperaturabhängigkeit der Fraßraten innerhalb beider Gattungen beobachtet. Die Daten der Individuen von *Idotea* spp. und *Gammarus* spp. ergaben in beiden Fällen Optimumskurven. Es wurde eine hohe Mortalität bei höheren Temperaturen als 25°C beobachtet. Die Fraßraten wichtiger Mesograzer könnten in Zukunft zeitweise zunehmen, bis eine Temperatur von etwa 20°C erreicht ist (Optimum) und anschließend aufgrund eines Zusammenbruchs des Stoffwechsels stark abfallen. Wenn Mesograzer aus einem Habitat verschwinden, kann dies schnell drastische Auswirkungen auf die dortige Lebensgemeinschaft haben. Indem wir zu allererst versuchen, einzelne Faktoren auf niederer trophischen Ebene zu verstehen, sind wir möglicherweise besser in der Lage, auch weitergehende und größere Dimensionen der Antworten auf den Klimawandel zu erfassen.

IV. Abstract

Climate change evoked numerous studies. Many of them concentrate on stress ecology. Temperature is considered to be a major factor. Keystone species are known to be able to structure a community or more widely a habitat. Mesograzers not only graze on algae (top-down) but also serve as food supply for smaller fish (bottom-up). We concentrated on the influence of temperature on the feeding rates of two Baltic Sea mesograzers: *Gammarus* spp. and *Idotea* spp. It was supposed, that the feeding rates appear in a kind of optimum curve. We conducted feeding experiments with organisms of both genera at temperatures from 5°C to 30°C. As feed, we used algae pellets. There was a temperature dependence in the feeding rate of both genera. The data of the faeces production of *Idotea* spp. and *Gammarus* spp. at different temperatures fit to an optimum curve. We observed a high mortality rate at high temperatures in both genera. The feeding rates of important mesograzers might temporary increase up to a temperature of about 20°C (optimum), but finally will also decrease because of a collapse in the metabolic rate. If grazers remove from a system, the consequences might be drastic changes within the community. By first try to understand single factors at lower trophic levels, we probably might be better able to address the whole dimension of the responses to climate change.

Keywords: Keystone species - Climate Change – Herbivory - Tolerance

1 Introduction

The Baltic Sea is the youngest sea in the Northern Hemisphere, which has its origin approximately 10000 to 15000 years ago after the last glacial. It is the second largest brackish environment and has a maximal depth of 460m and a mean depth of 60m.
The Baltic Sea belongs to the most productive coast ecosystems in the world, but at the same time it belongs to the most threatened ones (Waycott et al., 2009). As it borders on nine countries, it is widely impacted by influencing factors, such as habitat pollution and overfishing as well as eutrophication and habitat loss (Diaz & Rosenberg, 2008; Eriksson et al., 2009; Halpern et al., 2008).

The Baltic Sea is known for its low salinity with almost freshwater in certain regions. It is influenced and controlled by an exchange with the North Sea and freshwater.
Due to the low salinity, the Baltic Sea is a species-poor ecosystem (Bonsdorff, 2006). Subsequently, to be successful, species might have a broad salinity tolerance. They are often exposed to multiple stressors. These can have singular effects, but can also appear in an additive way (Darling & Cote, 2008; Wernberg et al., 2012). The varying in the oxygen level in the Baltic Sea forces populations to adapt to the changing conditions. That is why they often live at their physiological limit (Feistel et al., 2008). It is known that the populations of the Baltic Sea have a reduced genetic variation than other similar populations in the Atlantic. This might be due to an evolutional selection of extreme genotypes (Johannesson & Andre, 2006). Some species are called “key stone species”, as there is often only one dominant species.
Ecosystems can be influenced by Climate Change (Beaugrand et al., 2010; Pauli et al., 2012) and by consumer populations (Estes et al., 2011; Hughes, 1994; Paine, 1966; Polis, 1999). Extreme conditions and events are regarded as important driver for the ecosystem structure, as well (Walther et al., 2002).

1.1 Key stone species

A keystone species can be defined as one whose impact on its community or ecosystem is large, and disproportionately large relative to its abundance (Power et al., 1996). Bond (2001) and Mills et al. (1993) defined a keystone species as a species that can exert effects, not only through the commonly known mechanism of consumption, but also through such interactions and processes as competition, mutualism, dispersal, pollination, disease, and by modifying habitats and abiotic factors.

Regarding the above mentioned facts, important key stone species are the isopod *Idotea balthica* Pallas 1772 (WoRMS, 2015) and the bladder wrack *Fucus vesiculosus* Linnaeus 1753 (WoRMS, 2015), which will be described later.

Organisms of *Idotea* spp. are littoral and sublittoral crustaceans living at tidal shores (Naylor, 1955b). They are euryhaline organisms. That means that they are tolerant towards a wide range of salinities. This characteristic enables them to live in the brackish waters of the Baltic Sea (Haage, 1975; Jansson, 1967). Organisms of *Idotea* spp. are omnivores, but mainly graze on algae and algal debris, mainly the bladder wrack *Fucus vesiculosus* (Hemmi & Jormalainen, 2002; Naylor, 1955a, 1955b). In the Baltic Sea, three common species of *Idotea* can be found. These are *I. balthica*, *I. chelipes* Pallas 1766 and *I. granulosa* Rathke 1843 (WoRMS, 2015). They inhabit *Fucus* belts and eelgrass communities (Kautsky, 2008). All of these species are very tolerant to varying salinity.

Organisms of *Idotea* spp. are important primary consumers in littoral communities. They serve as food for several fish (bottom-up) (Haage, 1975, 1976; Hällfors et al., 1975; Jansson, 1967, 1974). They can also have remarkable grazing rates on several algae (top-down) (Leidenberger et al., 2012).

Breeding of *Idotea* spp. takes place synchronously between May and July. There are two phases of growth. One during the first two months and the other directly before maturity in spring. The largest population size can be found in autumn (Jansson & Matthiesen, 1971; Salemaa, 1979). In winter accumulated algal debris can serve as shelter and rich grazing ground if available, but the organisms often suffer from starvation and mortality (Salemaa, 1978, 1979).

Adult organisms of *Idotea* spp. seem to be under fluctuations during the year. This is for example caused by nutritive resources but can also occur due to a

decrease in predation by fish and increased productivity in warmer summers (Haahtela, 1984; Jansson & Matthiesen, 1971; Kangas et al., 1982; Salemaa, 1979, 1986).
Idotea spp. are among the most important herbivores in many systems (Duffy et al., 2001; Jernakoff et al., 1996; Kensley et al., 1995). Within *Fucus* belts organisms of *Idotea balthica* are the most important taxon related to their quantity (Korpinen & Jormalainen, 2008). There they constitute about 28% of the crustacean grazers, as well as in eelgrass communities (Bostrom & Bonsdorff, 2000; Schaffelke et al., 1995).

Besides this crucial mesograzers, amphipods build an important part of the communities. One of the amphipods is the genus *Gammarus* Fabricius 1775 (WoRMS, 2015). In the western Baltic Sea five species of *Gammarus* occur. These are *G. locusta* Fabricius 1775, *G. oceanicus* Segerstråle, 1947, *G. zaddachi* Sexton, 1912*, G. salinus* Spooner, 1947 *and G. d. duebeni* Lilljeborg, 1852 (WoRMS, 2015).
Gammarids live in different systems from freshwater to brackish environments like the Baltic Sea. (MacNeil et al., 1997). They live in and under substratum, which serves as shelter but also as food (Fitter & Manuel, 1994). Although gammarids are omnivores, most of the food is provided by algae (Barlöcher & Kendrick, 1973).The distribution of organisms of *Gammarus* spp. can be influenced by the oxygen level, acidity and pollution, as well as temperature and salinity (Jeffries & Mills, 1990; Whitehurst & Lindsey, 1990). Due to the fact that gammarids are euryhaline (Bulnheim, 1972), they are able to live in different salinity conditions, so also in the brackish Baltic Sea. They occur from the upper littoral zones to lower subtidal regions and have a broad salinity tolerance (Hartog, 1964; Jazdzeski, 1970; Kinne, 1954; Movaghar, 1964; Segerstrale, 1950).
Organisms of *Gammarus* spp. often occur together with *Idotea* spp. (Leidenberger et al., 2012).

As mentioned above, *Fucus vesiculosus* is one of the important key stone species in the western Baltic Sea. Most *Fucus* species occur in habitats, that a more or less stressful like subtidal or the intertidal areas. The distribution zone of *Fucus*

vesiculosus is also called “*Fucus* belt”. Compared to the whole Baltic Sea, this area is very species-rich. *F. vesiculosus* is an important organism as it serves as perennial habitat for many species and builds predictable a basis of the food web (Hawkins & Hartnoll, 1983).

It is already known that *F. vesiculosus* is able to build up a defence mechanism against biotic stressors. This is thought to be induced by for example grazing (Nietsch, 2009; Pavia et al., 1997; S. Rohde et al., 2004; Toth & Pavia, 2007; Weinberger et al., 2011). In this way, *F. vesiculosus* can control the richness of the herbivory community (Van Zandt & Agrawal, 2004).

Although a positive growth up to a depth of 5 to 6m has been observed in summer (Sven Rohde et al., 2008; Wahl et al., 2010), there is a reduction of 95% of the distribution range of *F. vesiculosus*, as it changed from a depth of 10m in the 1960s to a depth of just 1.5m today (Berger et al., 2004; Vogt & Schramm, 1991). Possible reasons for this decrease are eutrophication, epibiosis and grazing (Jormalainen & Ramsay, 2009; Krause-Jensen et al., 2009; Sven Rohde et al., 2008). Overfishing and overall climate change might also be factors (Ugarte et al., 2010). *F. vesiculosus* is thought to be very sensitive to future summer temperatures, which might have a huge impact on communities (Raddatz et al., in prep.). It is possible that high grazing rates by amphipods and isopods like *Gammarus* spp. and *Idotea* spp. are also able to reduce *Fucus* populations at several localities (Engkvist et al., 2000).

Fucus vesiculosus serves as habitat and food supply for the most abundant grazers in the Baltic Sea. These are the amphipod *Gammarus* spp. and the isopod *Idotea* spp. (Anders & Moller, 1983).

1.2 Mesograzing

Mesograzers have a structuring and decomposing role within the littoral communities. Amphipods and Isopods effect the biomass and diversity of vegetation (Brawley & Adey, 1981a, 1981c; Lopez et al., 1977; Robertson & Mann, 1980; Zimmerman et al., 1979). Herbivory is told to belong to the most important biotic factors regarding the development of a community at rocky shores like in the Baltic Sea (Dayton, 1975; Hawkins, 1981; Lubchenco, 1978; Lubchenco & Menge, 1978; Paine, 1974; Southward, 1964).

Herbivory by isopods, amphipods or gastropods can act in a mild but also in a severe and harmful way. A high density in herbivore populations can cause huge damage to the macroalgae. A positive effect is also possiblr, if they remove harmful epiphytes from algae (Brawley & Adey, 1981c; Nicotri, 1977; Shacklock & Croft, 1981). Thereby, they can affect stages of *Fucus* from germlings to adults (Dethier & Williams, 2009; Long et al., 2007; Pennings et al., 2000). There is a seasonal fluctuation of grazing pressure. It is low in winter and early summer when mesograzers are inactive or have low densities (Kotta et al., 2006). In contrast, grazing pressure is high in late summer when the density of juveniles is high (Engkvist et al., 2000; Korpinen et al., 2010).

Not only direct effects of mesograzers like on the biomass have been observed. They can also mediate influences of climate change in a direct way on lower trophic levels (O'Connor, 2009; O'Connor et al., 2011; Walther, 2004). Alsterberg et al. (2013) found out that mesograzers strongly affect the balance between bottom-up and top-down effects.

1.3 Temperature - a deciding factor

In 1990 (Lüning) a temperature of 20°C was told as highest water temperature, that lasted for longer periods than weeks within the natural distribution range of *Fucus vesiculosus.* Nowadays, the water temperature is already close to the limit in the upper 5m of the western Baltic Sea between June and August (Wahl, unpubl.). The water temperature is expected to rise for 3° to 5°C in the course of this century (BACC, 2008; IPCC, 2007). Ecosystems are already exposed to extremely high temperatures during summer (Wahl et al., 2010). Due to the low biotic diversity within the brackish Baltic Sea, there is a high risk of disturbance in the littoral communities (Hällfors et al., 1981).

Mesograzing is thought to increase with higher temperatures (BACC, 2008; IPCC, 2007). During former feeding experiments, Weinberger et al. (2011) detected a higher palatability of algae at 20°C. This might be due to a possible lower ability to induced defence which resulted higher grazing.

For *F. vesiculosus,* warming is documented to have stress effects from a temperature of 20°C (Pearson et al., 2009; S. Rohde & Wahl, 2008). Besides, in summer 2014, Raddatz et al. (in prep.) observed a drastic decrease within the populations of *Gammarus* spp. and *Idotea* spp., while the temperature increased

up to 29°C. There might have been a thermal border and the metabolic rate of algae and grazers might be influenced by temperature (Jenkins et al., 2001).
A lot of marine organisms already live close to their thermal tolerance limit (Hughes et al., 2003; Somero, 2002).
It is expected that a predicted climate change scenario will shift the environmental variables due to temperature, which may impact numerous species and marine coastal systems (Harley et al., 2006; IPCC, 2007; Parmesan, 2006). As suggested by Phillipart et al. (2003) there might be earlier spawning in several species due to warmer conditions, which might end up in a mismatch towards food supply.
Species with broad ecological niches might be able to better tolerate environmental changes. Such as species from the fluctuating Baltic Sea might be more flexible than species from more stable environments (Schneider, 2008). A consequence of a rising temperature in future, might be a shift along with their tolerance towards high temperature, as well as their capability to adapt to new conditions (Fields et al., 1993; Lubchenco et al., 1993).

1.4 Ambition of the thesis

In the last decades, numerous studies concerning climate change and its environmental effects were carried out. Many of them provide an insight into the stress ecology of different habitats. Single stressor and multiple stressor, which act in an additive way, were described. To be able to address the prospective responses of communities to climate change, it is important to do a first step: Understanding changes at low levels. The predicted 3° to 5°C increase in temperature may seem small, but can have huge impacts as not only direct but indirect effects of warming might be important (Wernberg et al., 2012).
Climate change has to be regarded from the lowest trophic level of communities, genera or even species. It is necessary to understand how organisms cope with changes.
Manipulating single stressors might help to understand and modulate possible scenarios of multiple ones.

As described above, temperature is a significant factor regarding the development of several habitats. Therefore, it was hypothesized, that there is a

temperature dependency of feeding rates of important mesograzers in the western Baltic Sea. Due to the studies of Pearson et al. (2009), Rohde & Wahl (2008) and Raddatz et al. (in prep.), this dependency is supposed to appear in an optimum curve with an optimum around 20°C.

H0: The feeding rate and so the faeces production increases with increasing temperature. There is a linear correlation between them.

H: The feeding rate and so the faeces production appears in a temperature dependent optimum with a quadratic function.

2 Material and Methods

2.1 Setting and preparation

The experiments took place at the GEOMAR Helmholtz Centre for Ocean Research in Kiel in the North of Germany. Organisms and Algae were collected next to the Lighthouse Bülk, Strande (54.45351°N 10.19729°E, Figure 2) in November 2014.

Figure 2 Map of the Kiel Fjord
Sample site (Bülk, Strande) is marked, ©2015 GeoBasis-DE/BKG (©2009), Google on 20/04/2015
20/04/2015

For the experiments 12 basins (Figure 1) with thermo-regulation (named A, B, C, D, E, F, G, H, I, K, L, M) were used (DC10, Thermo Scientific). They were prepared as follows: The basins were filled with distilled water up to three-quarters. Six jars, filled with water and closed by lids, were positioned into each basin. These jars had a diameter of 8.5cm and a height of 9cm and served as construction for the experimental jars, which had the same size. Another six jars without lids, the experimental jars, were positioned on top. Through this construction, it was guaranteed that the heating elements were completely covered with water and the experimental jars were surrounded by water up to about 2cm beneath the rim of the jars. A flexible tube system was prepared and connected to two air pumps to provide a good oxygen delivery for each organism.

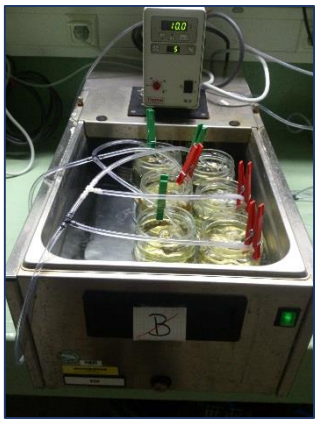


Figure 1 Picture of experimental thermo basin
Jar construction with flexible tube system, here: basin B (10°C), ©Elisa Gülzow 28/11/2014

For feeding experiments with *Idotea balthica*, an artificial feed has already been developed at the GEOMAR. Before starting the experiments, the collected thalli of *Fucus vesiculosus* were freeze-dried and grinded to a fine and homogeneous algae powder. This was stored in a Kautex to protect it from air moisture.

Fresh artificial feed was prepared for every new experiment of the organisms of one basin. For this purpose 1g algae powder was mixed with 4ml distilled water and 0,36g agar powder was mixed with 5ml distilled water. Two squares of baking paper (20 x 20cm) and one square of fly screen (5 x 5cm) were prepared. Additionally, a stable plate of plexiglass was laid out. The agar-water mixture was heated in the microwave at 800 watt until it boiled up. It was stirred at least once. The algae-water mixture was quickly filled into the hot mixture and stirred quickly. The resulting gel was put onto the fly screen and pressed between the two baking paper squares by using the plexiglass plate. After some seconds the gel was solid and had filled the squares of the fly screen. The fly screen could be cut into small squares for the experiment. Feed pellets of approximately 1cm x 1cm, composed of small screen squares of 11 x 11 squares were used for the experiment (Figure 3 Picture of feed pellet
Algae pellet used in the feeding experiments, ©Elisa Gülzow 12/12/2014).
All of the pictures were taken by Sony Xperia S, 12 MP.

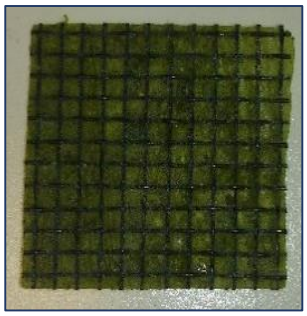


Figure 3 Picture of feed pellet
Algae pellet used in the feeding experiments, ©Elisa Gülzow 12/12/2014

2.2 Study organisms

The collected organisms were organisms of *Idotea* (Figure 4, Figure 5) and *Gammarus* (Figure 6 and Figure 7).

Animalia (Kingdom)
Arthropoda (Phylum)
Crustacea (Subphylum)
Malacostraca (Class)
Isopoda (Order)
Idoteidae (Family)
Idotea (Genus)

Figure 5 Taxonomic tree of *Idotea*
Classification of the Genus *Idotea* according to the World Register of Marine Species at http://www.marinespecies.org/aphia.php?p=taxdetails&id=118454 on 21/04/2015

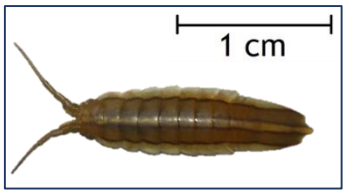


Figure 4 Picture of study organism I
Organism of *Idotea balthica* used in the experiment, @Elisa Gülzow 21/12/2014

The organisms of Gammarus were organisms of Gammarus locusta, *Gammarus oceanicus* and *Gammarus salina*. Organisms of *Idotea* were organisms of *Idotea balthica* and *Idotea granulosa*.

Animalia (Kingdom)
Arthropoda (Phylum)
Crustacea (Subphylum)
Malacostraca (Class)
Amphipoda (Order)
Gammaridae (Family)
Gammarus (Genus)

Figure 7 Taxonomic tree of *Gammarus*
Classification of the Genus *Gammarus* according to the World Register of Marine Species at http://www.marinespecies.org/aphia.php?p=taxdetails&id=101537 on 21/04/2015

Figure 6 Picture of study organism II
Organism of *Gammarus* sp. used in the experiment, @Elisa Gülzow 14/01/2015

2.3 Experiment

The entire feeding experiment took about three weeks. During this period, the organisms were inserted into experimental jars. Temperature was increased or decreased to the respective end temperature. Prior to the feeding experiments, the organisms had one week of acclimatization.

Detailed description: 72 experimental jars were prepared. They were filled with salt water from the GEOMAR system in the main building. The water came from the Baltic Sea and had already been sand-filtered by the system of the GEOMAR. Start temperature of the water in all basins was 12°C, which was the temperature of the Baltic Sea, when the experiment started. Thalli of *Fucus vesiculosus* were prepared and put into the jars. These had several branches to serve as feed and to give hold to the organisms. The length of each organism was measured by using a geometry set square and noted for later calculations and to get a reference value. The organisms were randomly put into the experiment jars, whereby there was only one organism in each jar. After that, the ends of the prepared air system were transferred into the experimental jars and fixed by a clothes peg, so that the air bubbles were not too strong and not too weak.
The temperature was changed twice a day towards the end temperature of the respective basin (Table 1). As described above, every basin started at a temperature of 12°C. The end temperatures were 5°C, 10°C, 15°C, 20°C, 24°C, 25°C, 26°C, 27°C, 28°C, 29°C and 30°C. There was also one basin where the temperature was kept at 12°C to control the influence of the experimental design. Once the end temperature in a basin has been reached, it was kept for seven days in order to allow for the organisms to acclimate prior the start of the experiment. After these seven days three steps of the feeding experiment were carried out. In the first step, the *Fucus* thalli of the respective jars were removed to make sure that the organisms were all hungry during the experiment and the results were not influenced by any other feed than the artificial.

Table 1 Plan of the temperature adaption period

Daily steps of the temperature adaption in °C, one-week-acclimatization, feeding experiment (red=no *Fucus* thalli, green=feed pellet added, purple=feed pellet removed + end of experiment)

Date	Basin											
	A	B	C	D	E	F	G	H	I	K	L	M
26.11.	12	12	12	12	12	12	12	12	12	12	12	12
27.11.	10	10	12	14	14	14	14	14	14	14	14	14
28.11.	8	10	12	15	16	16	16	16	16	16	16	16
29.11.	6	10	12	15	18	18	18	18	18	18	18	18
30.11.	5	10	12	15	20	20	20	20	20	20	20	20
1.12.	5	10	12	15	20	22	22	22	22	22	22	22
2.12.	5	10	12	15	20	24	24	24	24	24	24	24
3.12.	5	10	12	15	20	24	25	26	26	26	26	26
4.12.	5	10	12	15	20	24	25	26	27	28	28	28
5.12.	5	10	12	15	20	24	25	26	27	28	29	30
6.12.	5	10	12	15	20	24	25	26	27	28	29	30
7.12.	5		12	15	20	24	25	26	27	28	29	30
8.12.	5				20	24	25	26	27	28	29	30
9.12.	5				20	24	25	26	27	28	29	30
10.12.						24	25	26	27	28	29	30
11.12.						24	25	26	27	28	29	30
12.12.							25	26	27	28	29	30
13.12.									27	28	29	30
14.12.											29	30

After this starvation-phase of 24 hours, the second step was to remove the faeces of the former day and to insert a feed pellet into each jar for the next 24 hours. In the third step, the feed pellets were removed and the faeces were taken out of the jars.

During the temperature adaption, water was changed every second to third day by removing up to 50% of the ‘old’ water and replacing it by fresh water from the system. This fresh water had been stored in the respective basin and hence already had the right temperature. To exclude manipulation through a modified salinity due to evaporation, the water level was marked at the beginning and checked several times a day. A minor deviation from this level was compensated by adding some drops of distilled water. The *Fucus* thalli were replaced by fresh thalli every few days to make sure that the organisms have fresh feed during the adaption. Organisms of *Gammarus* were more active and swam around during the adaption time. Therefore, an additional piece of empty fly screen was inserted during the feeding experiment to give them a little more hold so that they were not twirled around by bubbles of the air system.

2.4 Sample processing

After the feeding experiment of 24 hours, the feed pellet was removed and the faeces of these 24 hours were collected by a syringe. The feed pellet and the collected faeces of each organism were stored separately to be able to assign the probes to the respective organism.

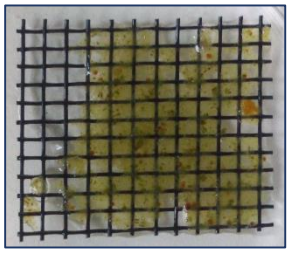


Figure 8 Feed pellet after the experiment
Empty squares can be seen, which have been eaten by a study organisms during the feeding experiment, @Elisa Gülzow 28/11/2014

The feed pellets were checked for empty squares (Figure 8). Squares were counted as an empty squares, when more than half of the square was eaten. The total numbers of eaten squares was noticed for each organism.

The organisms were put into the freezer for 20 minutes at -18°C to sedate them and were subsequently dried in a heating cabinet for 24 hours at 80°C. Afterwards, the organisms were weighed to determine their dry weight to get a reference value for the amount of faeces and eaten squares.

Figure 10 Filter flask and filtration device
Filtration equipment for the progression of the collected faeces probes, @Elisa Gülzow 28/11/2014

The faeces were filtered through glass microfiber filters with a pore size of 1.2µm (GF/C 25mm, Whatman) (Figure 9). The dry weight of these filters was already defined before filtration. A diaphragm vacuum pump (KNF), a filtration device and a filter flask (both Duran) were used for the filtration (Figure 10). The faeces-including filters were dried in the heating cabinet for 24 hours at 80°C. Finally the dry weights were determined by weighing the dried faeces-including filters. By subtracting the dry weight of the respective filters the exact dry weight of the faeces of each organism could be analysed.

Figure 9 Filtrate of Idotea sp.
Filtered faeces of a study organism before drying, @Elisa Gülzow 28/11/2014

For the analyses and representation IBM SPSS statistics 22, CurveExpert Version 1.40 and Microsoft Excel 2013 were used.

3 Results

There were two possible indicators for the feeding rates of *Idotea* spp. and *Gammarus* spp., the production of faeces and the empty fly screen squares of the feed pellets. Figure 11 and Figure 12 show correlations between the faeces production and empty fly screen squares, both standardised by the length of the organisms. There was a linear correlation with a coefficient of r=0.37 for the data of the organisms of Idotea spp. (Figure 11). A coefficient of r=0.59 could be found for a linear correlation between data of *Gammarus* spp. (Figure 12).

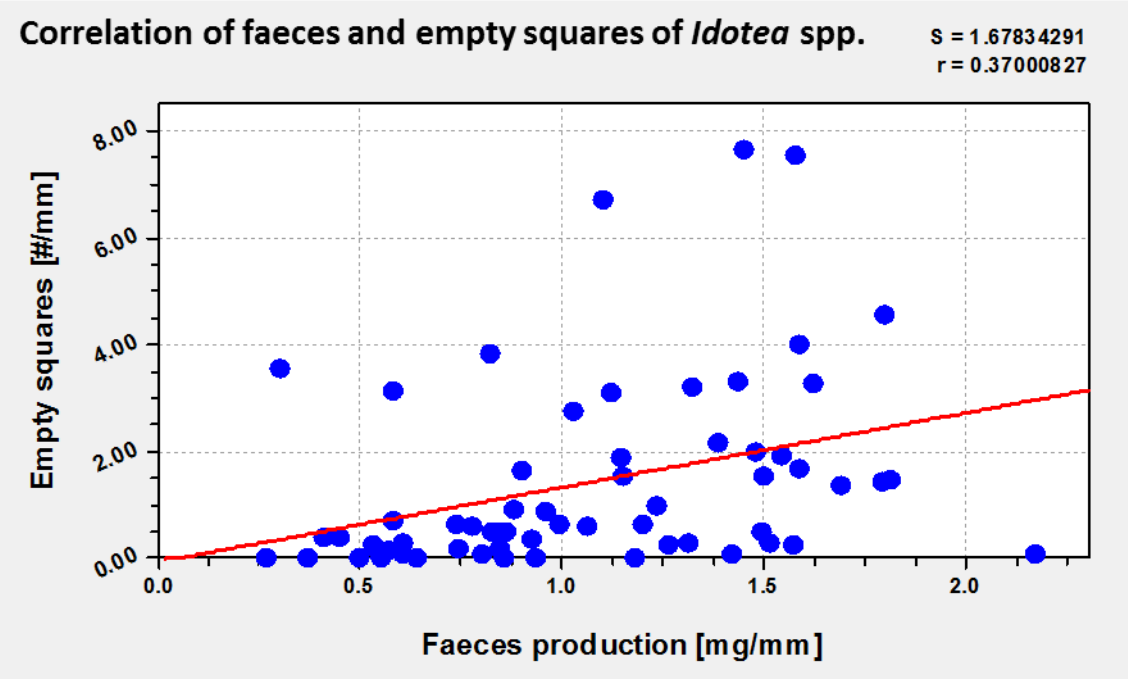


Figure 11 Correlation of faeces and empty squares of *Idotea* spp.
Correlation between quantity of faeces production and empty fly screen squares for the organisms of *Idotea* spp. Correlation coefficient r=0.37 and standard error S=1.68.

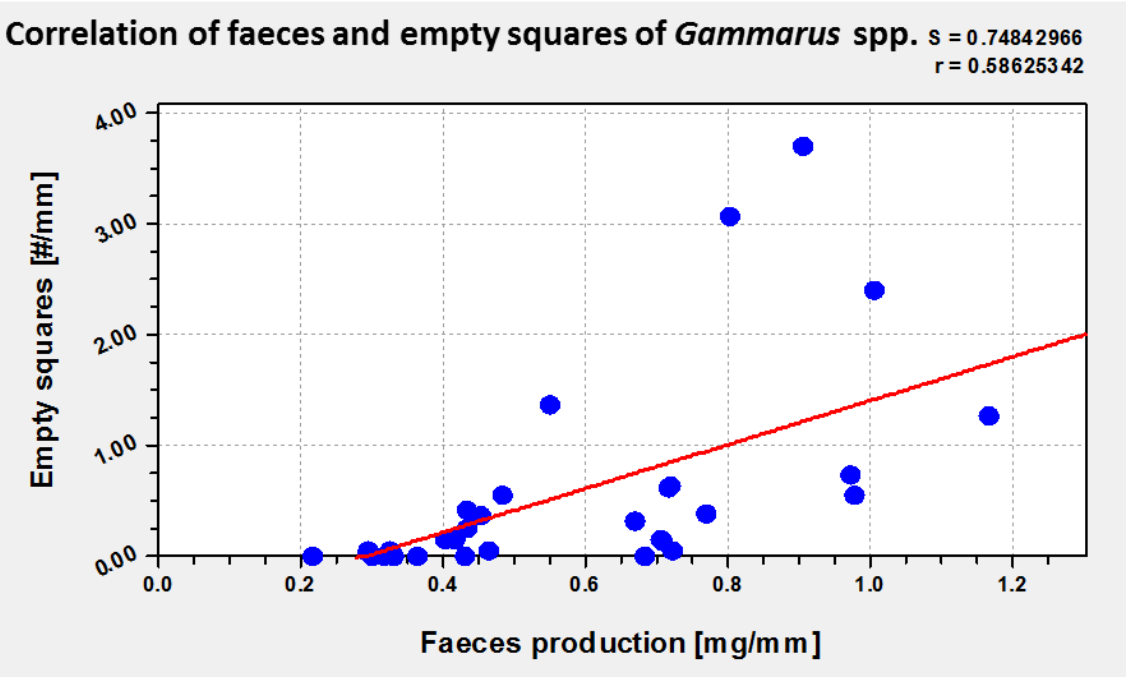


Figure 12 Correlation of faeces and empty squares of *Gammarus* spp.
Correlation between quantity of faeces production and empty fly screen squares for the organisms of *Gammarus* spp. Correlation coefficient r=0.59 and standard error S=1.75.

To compare the length and the dry weight of the organisms as standardizations for the resulting data, two kinds of correlations were made. These should help to decide about the best kind of standardization. The first correlation was done between the length and the dry weight of the organisms of *Idotea* spp. The same was done for *Gammarus* spp. A linear correlation with a coefficient of r=0.93 between the length [mm] and the dry weight [mg] of *Idotea* spp. (Figure 13.) and a coefficient of r=0.94 for *Gammarus* spp. (Figure 14 Correlation of length and dry weight of *Gammarus* spp.) could be determined.

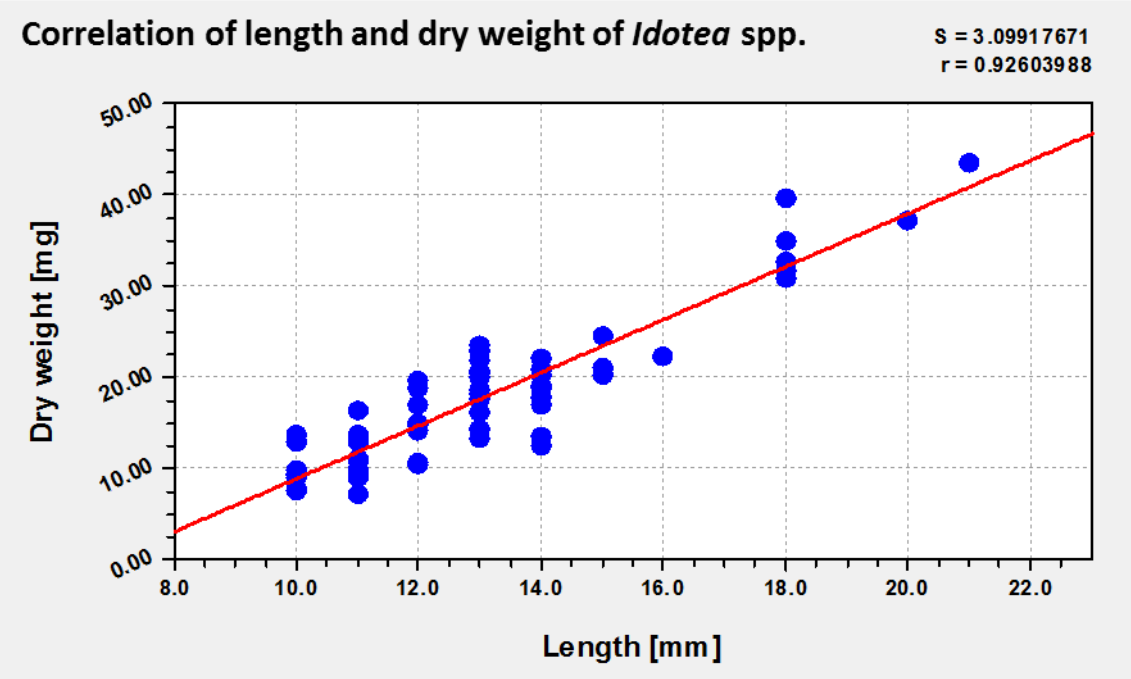


Figure 13 Correlation of length and dry weight of *Idotea* spp.
Length and dry weight of each organism of *Idotea* spp. with a linear regression. Standard error (S)=3.1 and correlation coefficient (r)=0.93.

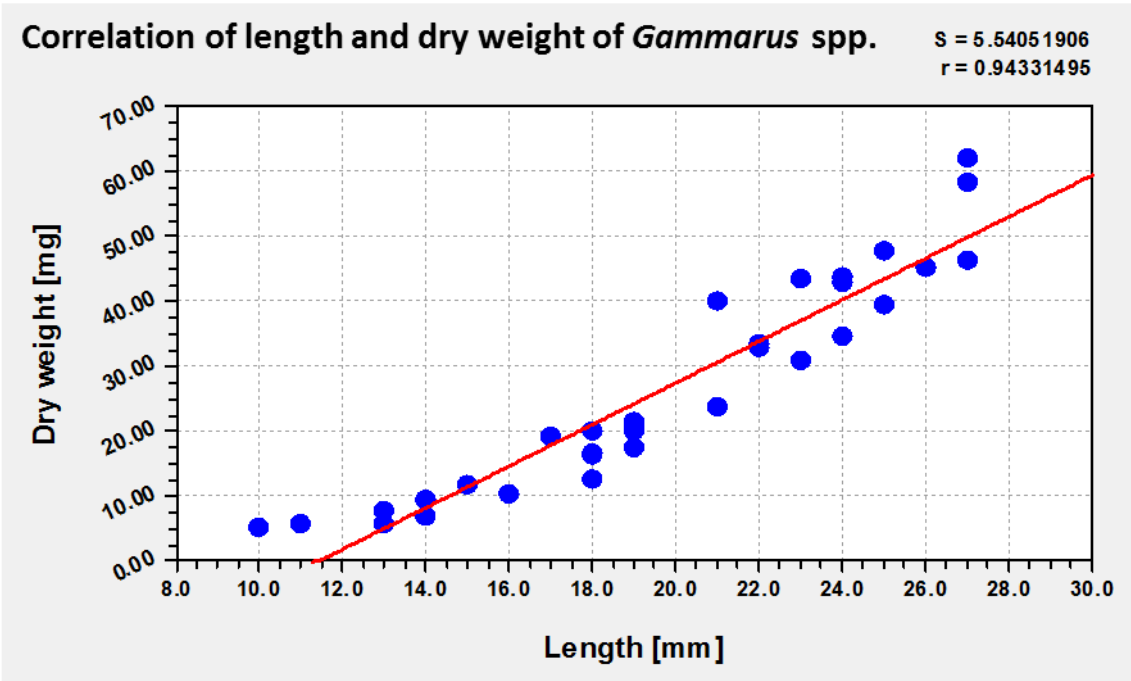


Figure 14 Correlation of length and dry weight of *Gammarus* spp.
Length and dry weight of each organism of *Gammarus* spp. with a linear regression. Standard error S=5.54 and correlation coefficient r=0.94.

3.1 *Idotea* spp.

The quantity of faeces production in dependence of temperature was tested on organisms of the genus *Idotea*. The resulting data were standardised by the length of the respective organisms. Therefore, results are presented in the quantity of faeces [mg] per millimetre of the organisms.

The control basin (C) with a temperature of 12°C was used to determine if the experimental design had an influence on the resulting data. The feeding experiment was conducted at the beginning and the end of the time and the faeces production was analysed. A t-test showed that these data were significantly not different (p=0.735). No mortality was observed in this basin.

The quantities of faeces production at different temperatures are indicated in Figure 15. A low faeces production was observed at 5°C and increased to the maximum of faeces production at 15°C. The quantity of faeces decreased continuously until 30°C. It could be established that the amount of faeces was similar at 5°C and at 30°C. For the analysis, a variance homogeneity test was carried out, which showed that the data were not homogenous (p=0.000). The equality of the mean values was tested by a Welch-test which was significant (p=0.000). Consequently, the data were not equal. As a post-hoc test the Scheffé-test was used to compare the mean values of the data. A significant difference between 5°C and 15°C (p=0.041) could be established. There was a significant lower faeces production at 5°C than at 15°C. No significant differences within the higher temperature steps were identified.

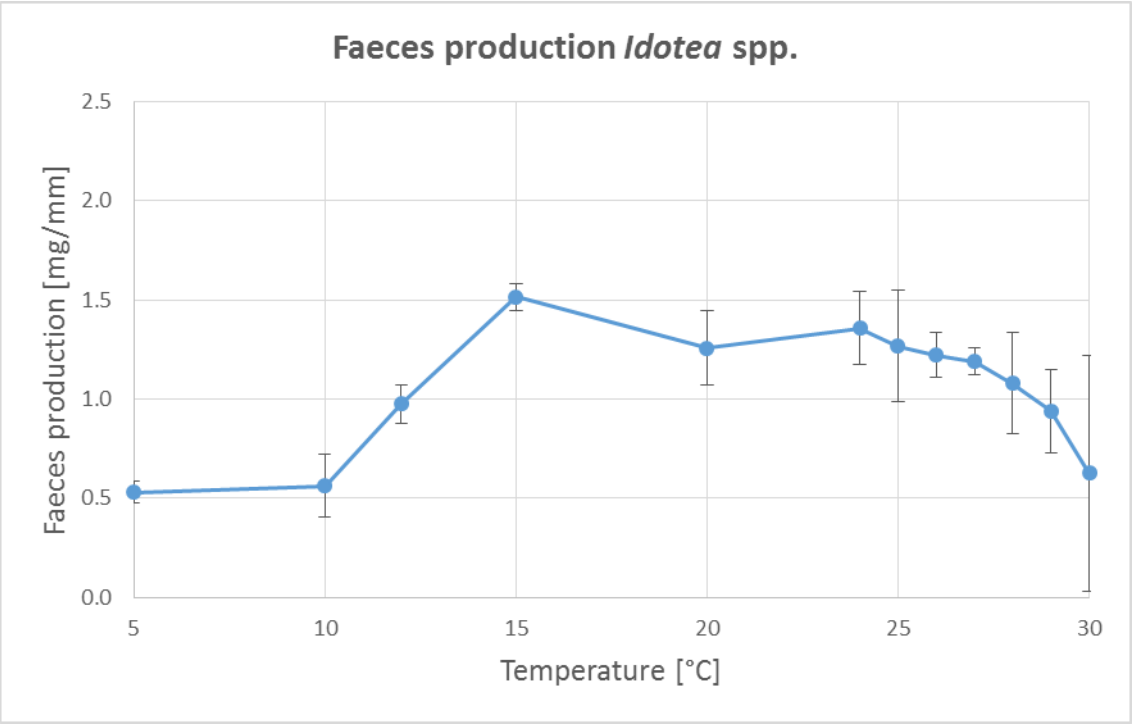


Figure 15 Faeces production *Idotea* spp.
Mean faeces production per experimental basin at different temperatures. Standardised by length of organisms. Significant difference (p=0.041) between 5°C and 15°C.

As an educated guess regarding the course of a potential curve could already be made, the CurveFinder of CurveExpert was used for further analyses to find a best-fitting curve for the mean faeces production of the organisms. Therefore, the mean values of the faeces production were used. The three best fitting curve models, the Polynomial Fit, Gaussian Model and the Sinusoidal Fit are illustrated in Table 3. The best fitting curve model was the Polynomial Fit with a correlation coefficient of r=0.90 (Figure 16). The formula and the corresponding parameters can be found in Table 2.

Table 3 Data-fitting curve models of faeces prod. of *Idotea* spp.
Three best fitting curve models. S= standard error; r= correlation coefficient.

	S	r
Polynomial Fit	0.16	0.90
Gaussian Model	0.16	0.89
Sinusoidal Fit	0.17	0.90

Table 2 Formula of curve model for *Idotea* spp.
Formula of the Polynomial Fit of the faeces production of *Idotea* spp. and parameters a, b, c and

$y = a + bx + cx^2 + dx^3...$	
a	0.357335718696
b	-0.0132064375084
c	0.00830413655621
d	-0.000249503396883

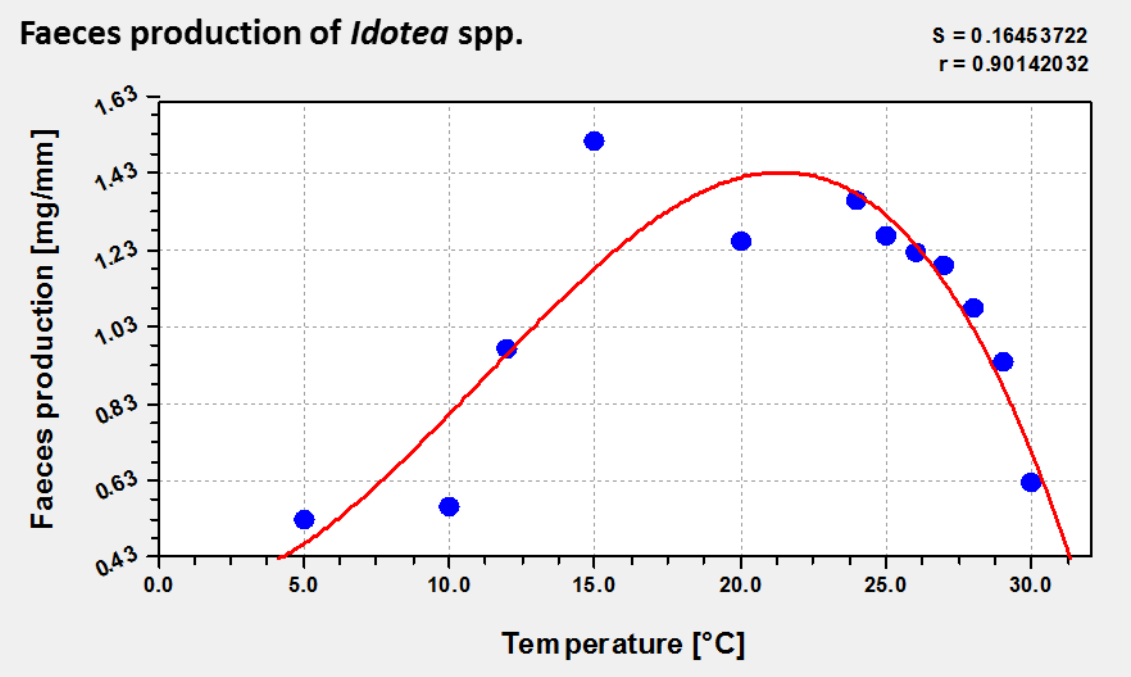


Figure 16 Polynomial Fit of faeces production of *Idotea* spp.
Faeces production of *Idotea* spp. at different temperatures. Best fitting curve model for resulting data. S= standard error; r= correlation coefficient.

In addition to the quantity of faeces production, the empty fly screen squares of the feed pellets of the corresponding organisms from different temperatures were inspected. These data were also standardised by the length of the organisms. The results are consequently presented in the quantity of empty squares per millimetre of the organism. Figure 17 shows the results of the mean values of empty fly screen squares at different temperatures. The quantity of empty squares increased to a peak at 15°C while there were less empty squares at 20°C. The next peak was at 25°C. There was a decrease in the quantity of empty squares until a temperature of 30°C was reached. To analyse these data, a variance homogeneity test released that the data were homogenous (p=0.004). The following ANOVA was not significant (p=0.209). There was no significant difference between the mean values of these data.

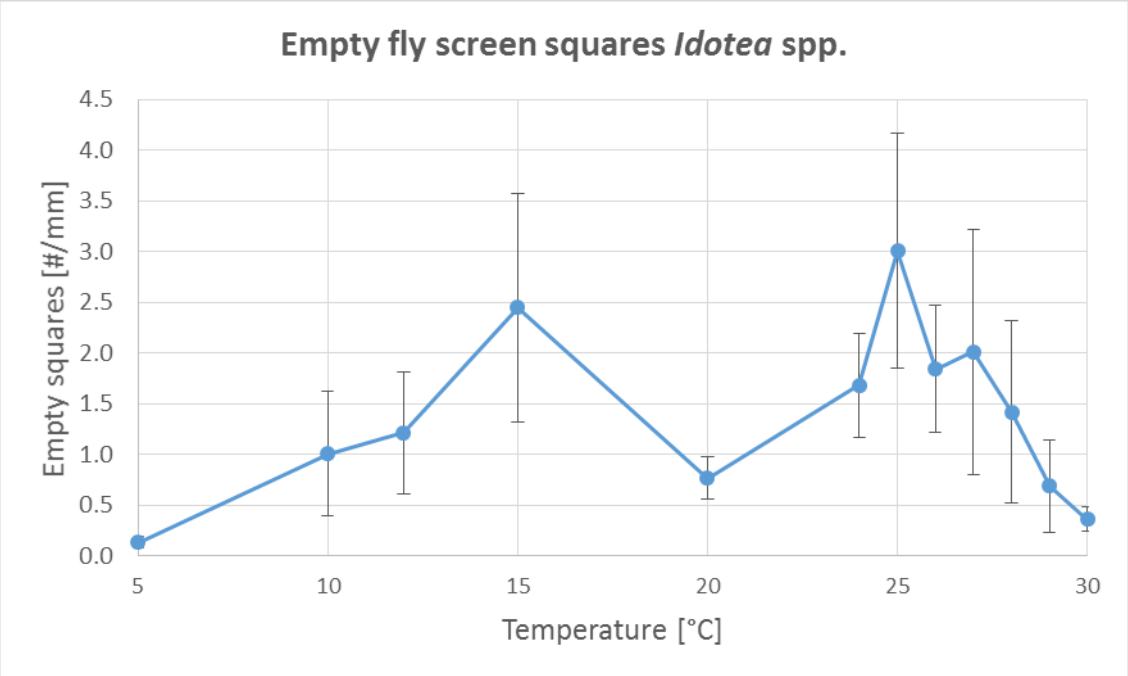


Figure 17 Empty fly screen squares *Idotea* spp.
Mean numbers of empty fly screen squares per experimental basin at different temperatures. Standardised by length of organisms.

For the data of the empty squares, a best-fitting curve model was searched, as well, by using the CurveFinder of CurveExpert. Table 5 shows the three best-fitting curve models for the data. As a Sinusoidal Fit is not appropriate for this kind of data set, Table 4 shows the formula of the quadratic curve model and its parameters. The Quadratic Fit had a correlation coefficient of r=0.65.

The Quadratic Fit of the empty squares is illustrated in Figure 18 Quadratic Fit of faeces production of *Idotea* spp..

Table 5 Data-fitting curve models of empty sq. of *Idotea* spp.
Three best fitting curve models. S= standard error; r= correlation coefficient.

	S	r
Sinusoidal Fit	0.57	0.83
Quadratic Fit	0.72	0.65
Polynomial Fit	0.73	0.69

Table 4 Formula of curve model for *Idotea* spp.
Formula of the Quadratic Fit of the empty squares of *Idotea* spp. and parameters a, b, c and

$y = a + bx + cx^2$	
a	-1.76358428055
b	0.393137086740
c	-0.0101167464573

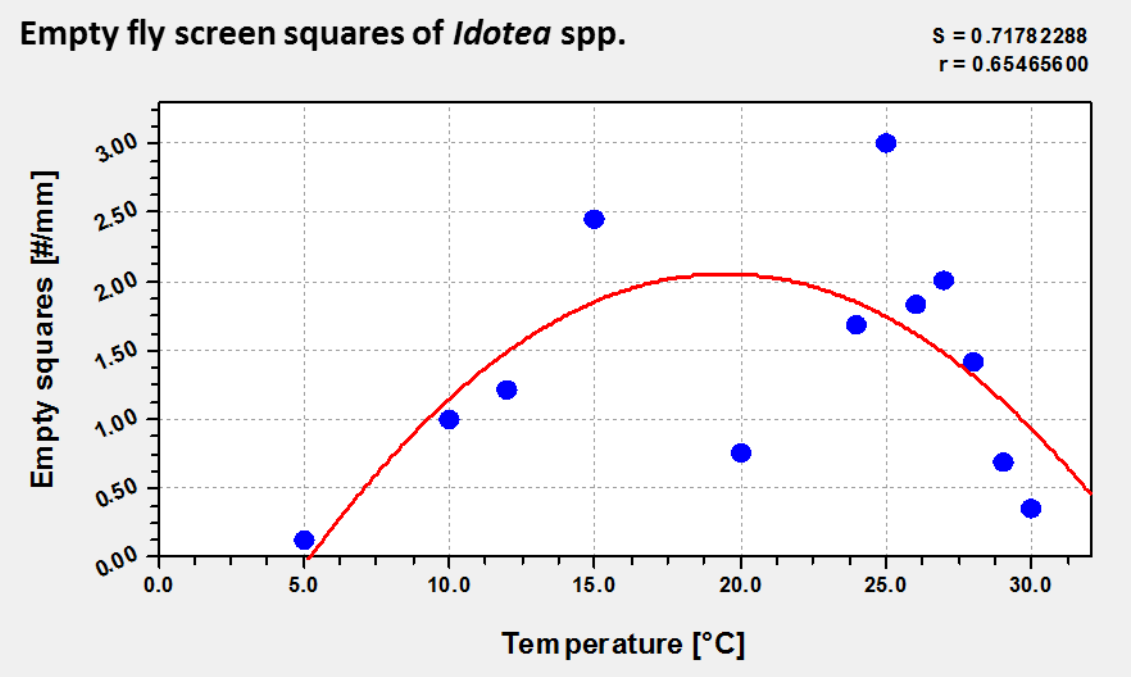


Figure 18 Quadratic Fit of faeces production of *Idotea* spp.
Empty squares of *Idotea* spp. at different temperatures. Best fitting curve model for resulting data. S= standard error; r= correlation coefficient.

As side effect, the mortality was considered for organisms of *Idotea* spp. during the whole experiment. The results are presented in the percentage of mortality in the respective basins and illustrated in Figure 19. There was no mortality in the basins which reached a final temperature of 5°C to 20°C or 25°C and 26°C while a third of the organisms of basin F that reached a temperature of 24°C, died. A high mortality was also observed at higher temperatures. Half of the organisms of basin K (28°C) and a third of the organisms of basin L (29°C). There was a mortality rate of 15% in the basins I (27°C) and M (30°C).

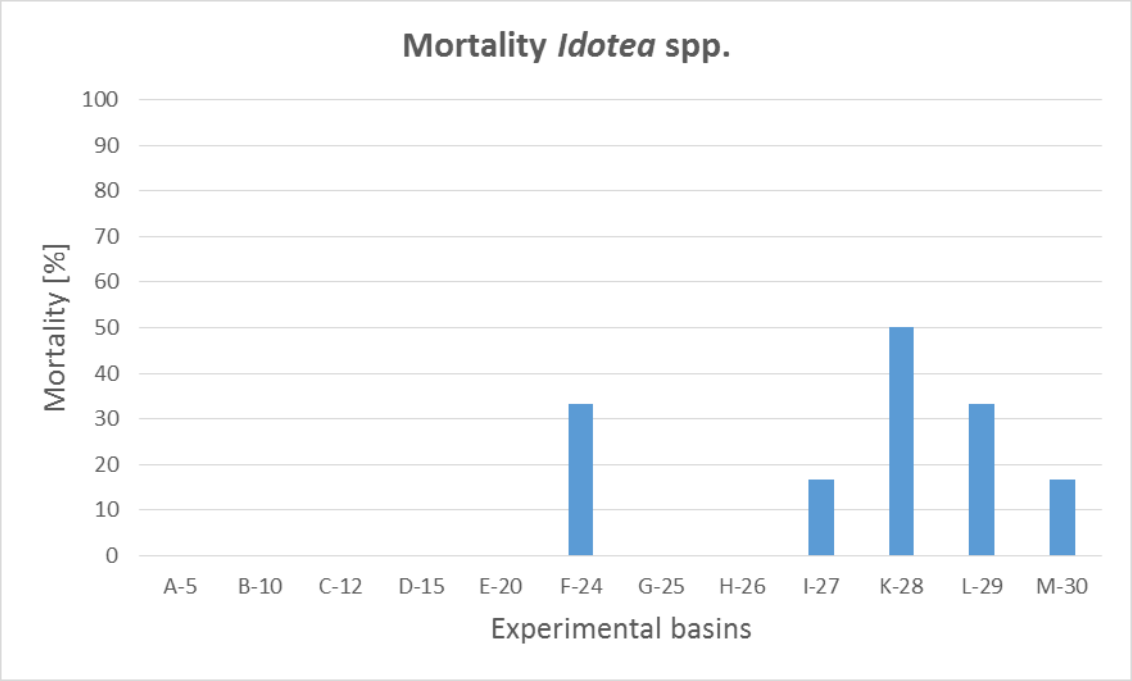


Figure 19 Mortality *Idotea* spp.
Percentage mortality per experimental basin. Six organisms in each basin.

3.2 *Gammarus* spp.

For the organisms of the genus *Gammarus* the quantity of faeces production was tested at different temperatures. These results were standardised by the length of the particular organisms, so that the results are presented in the mean quantity of faeces production [mg] per millimetre of organism.

A control basin (C) with a temperature of 12°C for *Gammarus* spp. was used in order to prove that the experimental design had no effect on the quantity of faeces production. The feeding experiment was carried out at the beginning and the end of the time. A t-test was used to analyse the faeces production of both experimental parts. It showed that these data were significantly not different ($p=0.359$). One of five organisms of this basin died during the keeping.

The results of the feeding experiments at the different temperatures are shown in Figure 20. There was an increase of faeces production from 5°C upwards, which had a peak at 20°C. A decrease of the production of faeces could be observed in the following basins: In the 27°C-basin (I), the faeces production was low like at the beginning 5°C. Due to mortality, there were no data for basins K, L and M. Data were analysed by a variance homogeneity test that showed that the data were homogenous ($p=0.955$). An ANOVA was not significant ($p=0.166$). There were no significant differences between the mean values of these *Gammarus* data.

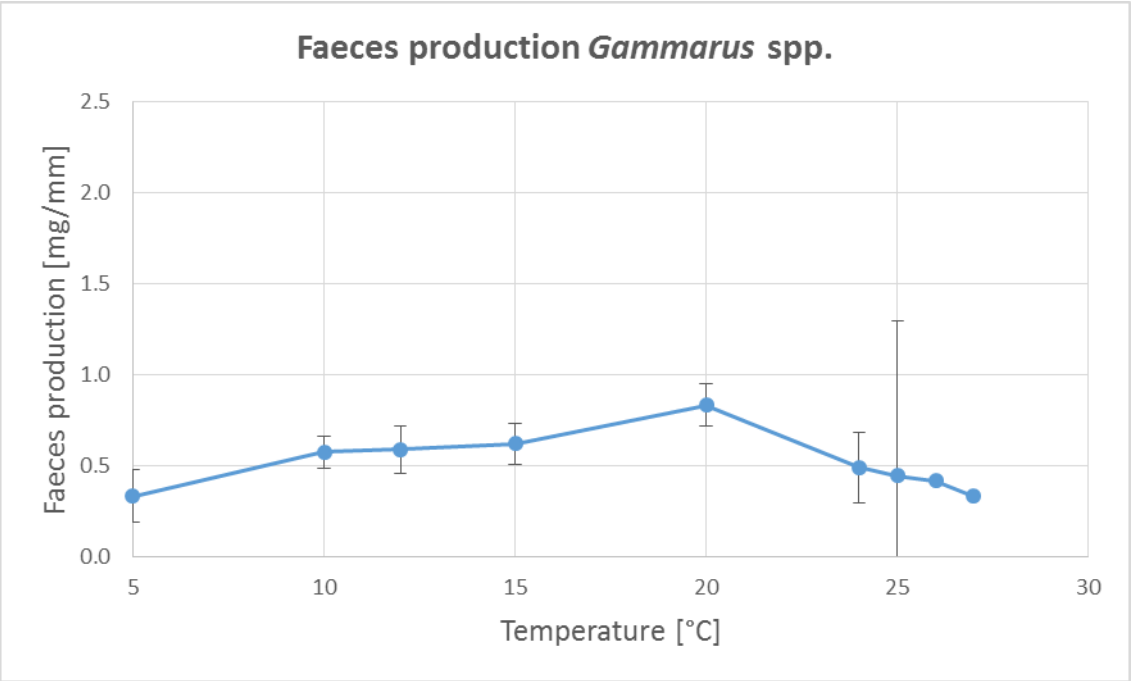


Figure 20 Faeces production *Gammarus* spp.
Mean faeces production per experimental basin at different temperatures. Standardised by length of organisms.

By using the CurveFinder of CurveExpert, the best fitting curve model for the data could be found. Here the data of every single organisms was used. The three best fitting models can be seen in Table 7 Data-fitting curve models of faeces prod. of *Gammarus* spp.. These were a Rational Function, Polynomial Fit and a Reciprocal Quadratic Function. The best fitting curve model was a Rational Function with a correlation coefficient of r=0.95. This curve is illustrated in Figure 21 Rational Function of faeces production of *Gammarus* spp.. The corresponding formula and its parameters can be found in Table 6.

Table 7 Data-fitting curve models of faeces prod. of *Gammarus* spp.
Three best fitting curve models. S= standard error; r= correlation coefficient.

	S	r
Rational Function	0.06	0.95
Polynomial Fit	0.07	0.93
Reciprocal Quatratic	0.08	0.90

Table 6 Formula of curve model for *Gammarus* spp.
Formula of the Rational Function of the faeces production of *Gammarus* spp.

$y = (a + bx) / (1 + cx + dx^2)$	
a	0.269134662883
b	-0.00736722372256
c	-0.080085110015
d	0.00189739116595

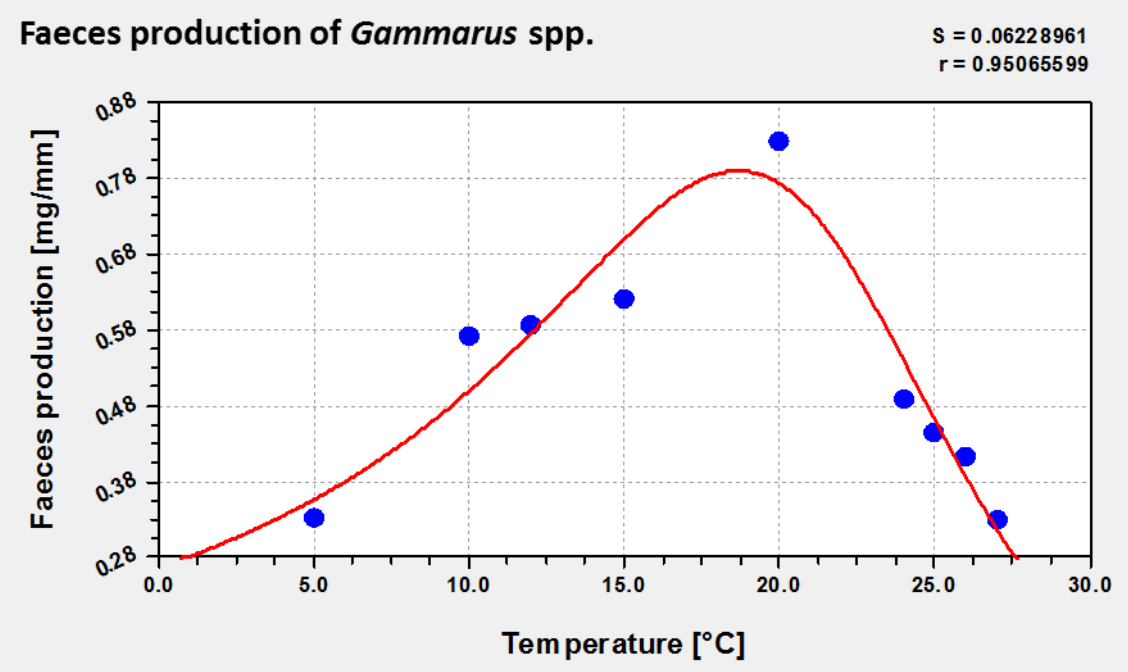


Figure 21 Rational Function of faeces production of *Gammarus* spp.
Faeces production of *Gammarus* spp. at different temperatures. Best fitting curve model for resulting data. S= standard error; r= correlation coefficient.

For the organisms of *Gammarus*, the number of empty fly screen squares of the feed pellets was also quantified. The results were standardised by the length of the organisms. Collected data can be seen in Figure 22. The feed pellets of basin A (5°C) showed a very low quantity of empty squares. There was a continuous increase up to a peak in the basin with 20°C. The next small peak could be observed at 25°C. There were no empty or little empty squares in the pellets of the basins with a final temperature of 24°C and 27°C. No results can be given for the basins with temperatures of 28°C to 30°C due to mortality. A variance homogeneity test showed that the data were homogenous (p=0.028). A following ANOVA was not significant (p=0.596). There was no significant difference between the mean values of the empty squares.

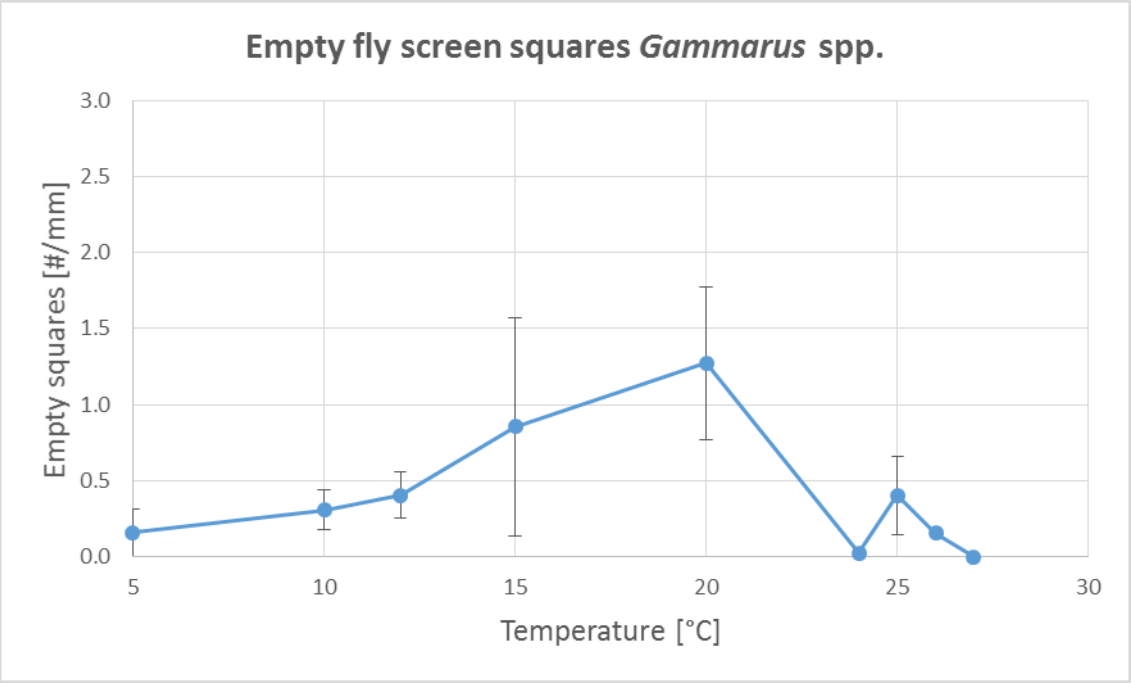


Figure 22 Empty fly screen squares *Gammarus* spp.
Mean numbers of empty fly screen squares per experimental basin at different temperatures. Standardised by length of organisms.

The CurveFinder of CurveExpert was again used for these data. A best-fitting curve model was searched for the data of the empty fly screen squares of the experiments of organisms of *Gammarus* spp. Table 9 Data-fitting curve models of empty squares. of *Gammarus* spp.shows the three best-fitting curve model for our data. As the Sinusoidal Fit is not appropriate to the data, the Polynomial Fit is illustrated in Figure 23. This curve had a correlation coefficient of r=0.82. Table 8 shows the formula of this curve and the respective parameters.

Table 9 Data-fitting curve models of empty squares. of *Gammarus* spp.
Three best fitting curve models. S= standard error; r= correlation coefficient.

	S	r
Sinusoidal Fit	0.23	0.90
Polynomial Fit	0.30	0.82
Quatratic Fit	0.33	0.73

Table 8 Formula of curve model for *Gammarus* spp.
Formula of the Rational Function of the empty squares of *Gammarus* spp

$y = (a + bx) / (1 + cx + dx^2)$	
a	0.480727870074
b	-0.163241843340
c	0.0210185552121
d	-0.00058749915693

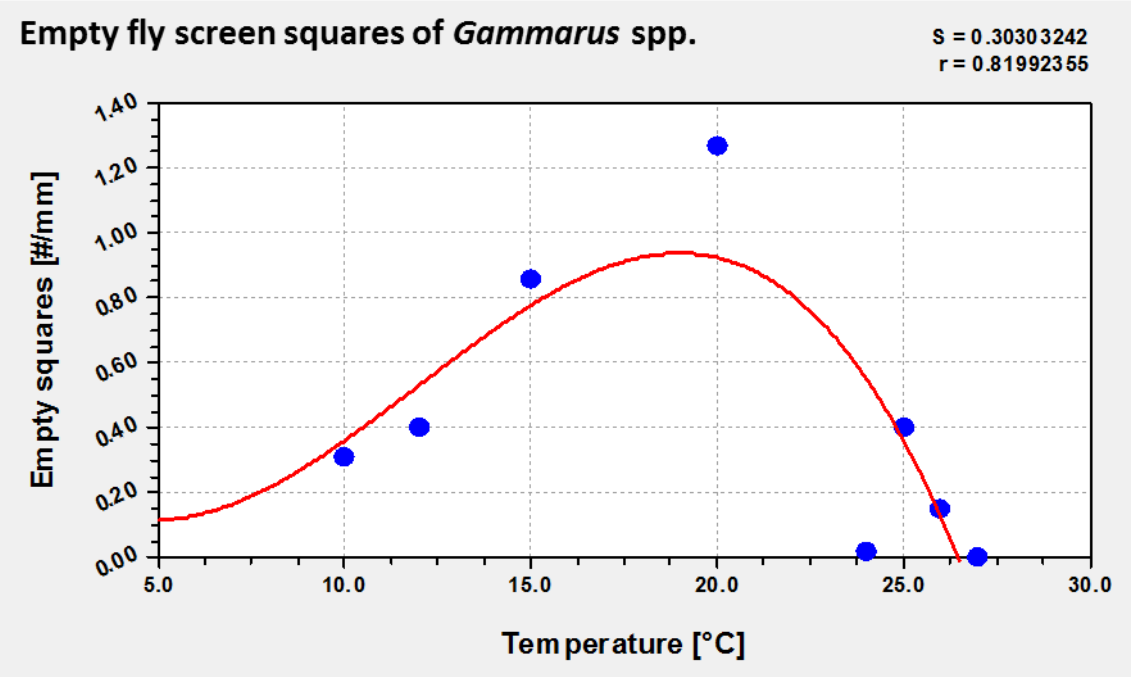


Figure 23 Polynomial Fit of empty squares of *Gammarus* spp.
Empty fly screen squares of *Gammarus* spp. at different temperatures. Best fitting curve model for resulting data. S= standard error; r= correlation coefficient.

A side effect of the experiments of *Gammarus* spp. was also the mortality. This factor was monitored and noticed during the whole experiment. Figure 24 shows the percentage of dead organisms in the respective basins. As basins A to D started with 5 organisms, the percentages of these basins refer to a 100%-rate of five organisms instead of six. This was due to the quantity of organisms. A low mortality of 20% could be established in the lower tempered basins. No mortality was monitored in the basins, which reached 15°C and 20°C. The 24°C-basin showed a high mortality of two-thirds. In the basin that reached 25°C, a low mortality of less than 20% was realized. High mortality rates could be detected at higher temperatures. Basins H (26°C) and I (27°C) had a mortality of more than 80%. In the basins with temperatures between 28°C to 30°C, all of the organisms of *Gammarus* died.

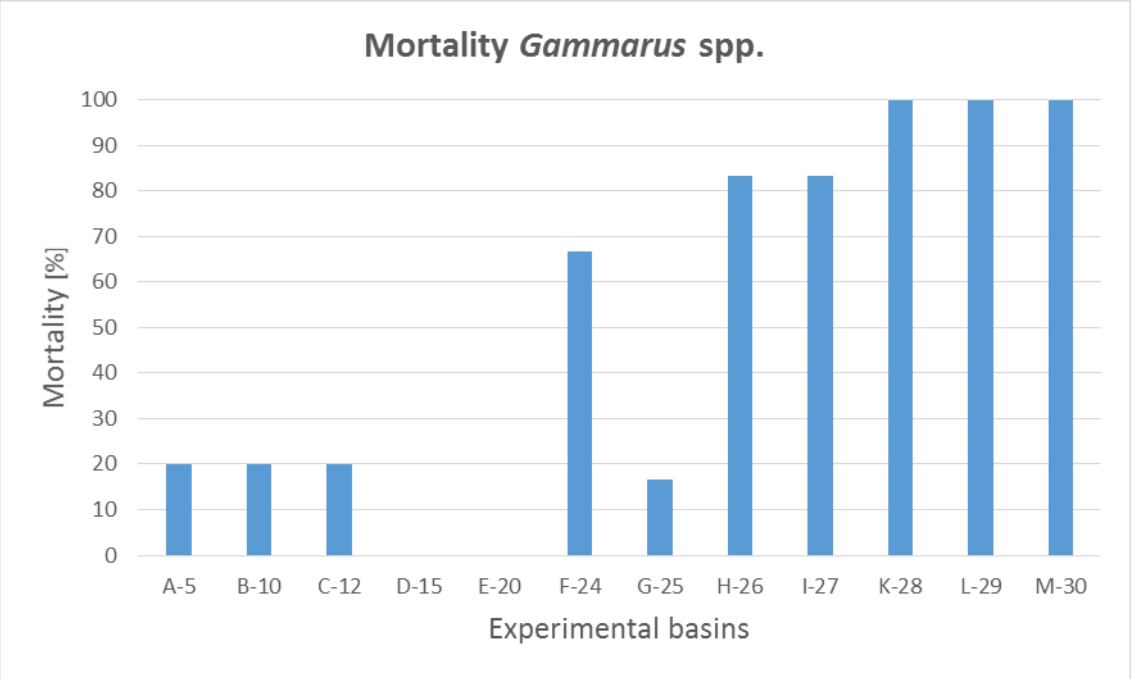


Figure 24 Mortality *Gammarus* spp.
Percentage mortality per experimental basin. A-D with 100%-rate of five organisms, other basins with six organisms.

3.3 Result summary

No significant results could be found by using the quantity of fly screen squares as indicator for the feeding rates of organisms of *Idotea* and *Gammarus*. During the experiments of the organisms of *Idotea* spp., a significant higher mean faeces production could be established at a temperature of 15°C than at a low temperature of 5°C. During the experiments of the organisms of *Gammarus* spp., no significant results could be found regarding the quantity of faeces production. In both genera, mortality was higher in basins that reached higher temperatures of more than 25°C than in basins that had a lower final temperature. Especially, organisms of *Gammarus* spp. died when higher temperatures were reached. The data of the faeces production of *Idotea* spp. at different temperatures fit to a polynomial curve model. The data of the faeces production of organisms of *Gammarus* spp. fit to a rational curve model. The experimental time had no effect on the results.

4 Discussion

4.1 Result discussion

Prior to analysing the resulting data of the feeding experiments, the task was to find out the possible indicator suitable for the analyses. There was the possibility to indicate the feeding rates of the organisms of *Idotea* spp. and *Gammarus* spp. by quantifying the empty fly screen squares of the feed pellets. A second possible indicator for the feeding rates was to quantify the faeces production. A correlation was done between the faeces production and the empty fly screen squares of the experiments of both genera. In both cases, neither for *Idotea* spp. nor for *Gammarus* spp., there was a very good linear correlation between the data sets. The method of quantifying the empty fly screen squares seemed to be very imprecise. This will be explained more detailed in the method discussion. Therefore, the faeces production was more suitable for the analyses.

A second task was to find out the best way for a standardization of the data. The reason for it was, that the organisms were not of the same size, so that for a comparison there had to be a kind of standardization. A correlation of the length and the dry weight of the organisms of *Idotea* spp. and *Gammarus* spp. was done. There was a good linear correlation between the data sets. It could be assumed that both, the length and the dry weight, could be used as standardisation value. This was tested during a third correlation between the faeces production standardised with the length and the faeces production standardised with the dry weight. We also found a good linear correlation for the correlations of organisms of *Idotea* spp. and *Gammarus* spp. Obviously both could be used as standardisation value. Here, the length was used to standardise the data.

4.1.1 Idotea spp.

The faeces production of organisms of *Idotea* spp. in dependence of temperature was investigated as an indicator for the feeding rate.

When we compared the mean values of the faeces production of the different tempered basins, we detected a significant difference in the mean values belonging to 5°C and 15°C. Subsequently, it can be supposed, that there is indeed a higher feeding rate at 15°C than at 5°C. As explained above, the resulting data of the quantification of empty fly screen squares seemed to be imprecise and were influenced by the feeding behaviour of the organisms as they often only ate at the surface of the feed pellets. These data were not appropriate to be used as indicator for the feeding rate.

The assumption was that there could be a kind of optimum curve for the feeding rates of organisms of Idotea spp. A polynomial curve model was found as best-fitting model for these data. While this curve model had a correlation coefficient of r=0.90, the previous assumption could be largely confirmed. It was supposed that there would be a low metabolic rate at low temperatures which might be followed by a low feeding rate. An increase was assumed up to a temperature of approximately 20°C with a subsequent more abrupt decrease. The curve model of the faeces production of *Idotea* spp. showed exactly the course that was expected. The curve showed a slow increase of the faeces production, an optimum at the beginning of 20°C and a decrease of the faeces production up to 30°C.

Observations during the experiment showed a clear difference in the vitality of organisms at temperatures of 5°C and 21°C. The organisms in the 5°C-basin moved very slowly and seemed lethargic. The organisms in the basin that reached 21°C were very active and swam around a lot. These observations suited to the resulting data. The low vitality at lower temperatures could be explained by a low metabolic rate which takes fewer energy and makes it possible to calm down the feeding rates.
As assumed, the metabolic rate seemed to increase to a kind of optimum, which was followed by a higher vitality and a higher feeding rate. A sudden decrease in

the feeding rates could be established, when the temperature exceeded this optimum. A lower vitality could be observed at this temperatures. This could be due to a decrease in the metabolic rate because of heating stress.

The mortality rates of the organisms of *Idotea* spp. showed a higher mortality at the upper temperatures than the lower ones. It seemed as if lower temperatures could be tolerated more easily. The higher temperatures above the middle 20°C were often followed by a high mortality rate. This matched the former assumptions that higher temperatures could constitute a problem for the surival of the organisms.

The high mortality in basin F (24°C) was proved by looking for any technical influences like light or a false temperature on the display of the experimental basin. No indication for the high mortality could be found. This temperature might be a critical point for the organisms. The organisms of basin F might also have been more sensitive than the others.

4.1.2 Gammarus spp.

For the organisms of *Gammarus* spp., the faeces production was also quantified in dependence of the temperature as an indicator for the feeding rate.

During a comparison of the mean values of the faeces production from organisms of *Gammarus* spp., no significant differences could be found. The quantification of the empty fly screen squares were, as well, rather imprecise as the organisms of *Gammarus* spp. often only ate at the surface of the feed pellet, but more often just ate from the margin of the pellet. Therefore, these results should be considered with caution. The faeces production might have given better resulting data about the feeding rates of the organisms of *Gammarus* spp. No statement can be made for the organisms in the basins that reached temperatures of 28°C and above. There was a mortality rate of 100%.

It was guessed that data could appear in a kind of optimum curve for the faeces production of *Gammarus* spp., as well. A Rational Function was considered to be the best-fitting curve for the data with a correlation coefficient of r=0.95. It was expected, that there would be an increase of the feeding rate with an optimum around 20°C and a more or less sudden decrease. The rational curve showed these course of the results. The optimum was situated slightly below 20°C. There was indeed a slower increase and a sudden decrease of the faeces production.

During the experiments, the mortality of the organisms of *Gammarus* spp has also been observed. Mortality could be established in every basin except basin D and E that reached 15°C and 20°C. It can be assumed, that organisms of *Gammarus* spp. are very intolerant to temperatures above 20°C. In that basins up to 100% of the organisms died. In basins A to C, only one organism died. Thus, these temperatures might not create such huge problems like higher ones. During the experiments of the organisms of *Idotea* spp. a higher mortality in basin F, which reached 24°C, was detected. This basin was inspected for any other influences but no external reason for the high mortality rate could be found. Therefore, it could be supposed, that there might be a critical point for the metabolic rate and surviving of the organisms. Another reason could be, that this was just coincidental.

4.1.3 Comparison and summary

The course of the faeces production over the different temperature steps were very similar between both genera. Both showed a slow increase and a more or less sudden decrease in the production of faeces. Both genera seemed to better tolerate low temperatures than high temperatures. The organisms of *Gammarus* spp. seemed to be more mortality-prone than the organisms of *Idotea* spp. The best-fitting curve model showed an optimum above 20°C for *Idotea* spp. and an optimum below 20°C for *Gammarus* spp. This might be an indicator for a lower tolerance limit of *Gammarus* spp. towards temperature.

Mesograzing was already presumed to increase beyond temperatures of 15°C (BACC, 2008; IPCC, 2007). Due to a drastic decrease of populations of *Gammarus* spp. and *Idotea* spp. at a temperature of 29°C (Raddatz et al., in prep.) an optimum of the feeding rates was thought to be situated somewhere in the middle of these two temperatures.

The observation of a decrease of the mesograzers populations (Raddatz et al., in prep.) confirm the mortality during the experiments of this study. A possible reason might be a collapsing metabolic rate. A dependency of the metabolic rate and temperature was already guessed by Jenkins et al. (2001).

Consequently, as it was determined that the faeces production can be seen as indicator for the feeding rates.
As null hypothesis we supposed that the feeding rate and so the faeces production increases with increasing temperature and that there is a linear correlation between them. This can be rejected. It can be supposed that the feeding rates of the organisms of *Idotea* spp. and *Gammarus* spp. appear in an optimum curve. This validates the previous alternative hypothesis that there might be a dependency between the feeding rate and temperature in a non-linear way but a quadratic function. The optima were situated slightly above (*Idotea* spp.) and beyond (*Gammarus* spp.) 20°C.

4.2 Method discussion

For a critical reflection of the experimental design, there will be a method discussion in the following.

To quantify the feeding rates of organisms of *Idotea* spp. and *Gammarus* spp., the quantity of empty fly screen squares of the feed pellets as well as the quantity of faeces production of the respective organisms has been considered. The quantity of empty fly screen squares must be considered critically. Obviously, the empty fly screen squares do not exactly show the quantity that has been eaten. During the quantification of the fly screen squares, it could already be observed, that many of the squares were just eaten at the surface. Some of the pellets were eaten at the margin and were therefore not counted as empty squares because it was not within the used 11 x 11 squares of the feed pellet. Consequently, these squares were neither counted as empty squares nor quantified for the feeding rate, although the respective organism has eaten something.
To sum that up, this method of quantification might have been rather imprecise. That could also be the reason, why the results of this experimental part were not significant and had large standard errors. Therefore, the feeding rates should be quantified by taking the faeces production of the respective organisms as indicator.

The organisms of *Idotea* spp. as well as of *Gammarus* spp. were not of the same size. Therefore, it was difficult to compare the data. A reference value to standardize the results had to be found. In both cases the length of every organism was measured before it was put into the experimental jars. Additionally, the dry weight of the organisms was measured after the feeding experiments. As described in the result discussion, both values were appropriate. For the standardization the lengths of the organisms was used.

As illustrated in Table 1, organisms that were put in the basins, which reached higher temperatures, stayed there for a longer time than organisms in the basins, with a final temperature of for example 5°C. Therefore, the influence of time was tested by using a control basin, in which the temperature was kept at the starting temperature for the whole time, but although passed through the feeding

experiment like all other basins. The feeding experiment was carried out at the beginning, immediately after inserting the organisms in the experimental jars, and at the end of the acclimatization period of seven days. The resulting data were compared by a t-test. This test showed, that there was no difference between these two data sets of feeding experiments. The time which the organisms stayed in the experimental jars had no influence on the resulting quantity of faeces production.

To exclude that the results were influenced by feed, an artificial feed pellet was prepared. This was already used for other feeding experiments at the GEOMAR. All pellets had the same size and consisted of homogenous algae powder, so that the ingredients of the pellets were identical. Due to the fact that the pellets were prepared freshly prior to each experiment, none of them might have been more palatable or attractive.

The organisms were kept individually to exclude an influence due to feed competing or space competition.

The amount of parallel experiments within one basin was limited by the size of the basins. The water for the next water change had to be stored in the respective basin as well, so that no more than six jars could be arranged within one basin. Moreover, additional repetitions of the whole experiment were limited by the amount of organisms. Due to the season, there were not enough organisms to conduct the experiments once or several times again.
For further investigations it might be useful to conduct the experiments with more organisms or carry out more repetitions to get a larger amount of data.

4.3 Prospects

Referring to the introduction, herbivory is told to belong to the most important biotic factors of climate change (Dayton, 1975; Hawkins, 1981; Lubchenco, 1978; Lubchenco & Menge, 1978; Paine, 1974; Southward, 1964).
Due to the results of this thesis, it can be expected that while temperature decreases during the century (BACC, 2008; IPCC, 2007), the feeding rates of important mesograzers will temporary increase up to a temperature of about 20°C, but finally will also decrease because of a collapse in the metabolic rate of mesograzers.

Nowadays, water temperature is already close to the limit in the upper 5m of the western Baltic Sea between June and August (Wahl, unpubl.) and ecosystems are exposed to extreme temperatures during summer (Wahl et al., 2010).
Due to the low biotic diversity in the brackish Baltic Sea with just some dominate and specialised species and thus a high risk of disturbance in the littoral communities (Hällfors et al., 1981), the loss of a single species can have wide consequences. A single dominant species cannot be easily replaced by another species, because there is none.
Mesograzers have a structuring and decomposing role in the littoral communities as they do not only graze on algae (top-down) but also serve as food supply for smaller fish (bottom-up) (Brawley & Adey, 1981a, 1981c; Lopez et al., 1977; Robertson & Mann, 1980; Zimmerman et al., 1979). Consequently, if grazers remove from a system, the consequences might be drastic changes within the community. This may have consequences on a whole habitat or environment. Species like organisms of *Gammarus* spp. and *Idotea* spp. inhabiting the fluctuating Baltic Sea might be more flexible than species from more stable environments (Schneider, 2008), but this flexibility seems to have its limits at higher temperatures.

These facts show, how important it is, to start understanding climate change at low levels. A lot of work has to be done to be able to understand the interaction of multiple biotic and abiotic stressors. But in this way we might be able to address the whole dimension of responses to climate change.

V. Appendix

Appendix 1 Recipe for feed pellets

Original recipe of the artificial algae feed pellets of the GEOMAR
of the GEOMAR

IFM-GEOMAR
Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

Datum: 11.04.2008
Verfasser: N. Stärck

Futter-Pellets aus Agar

1. **1g Algen-Pulver + 4 ml H2O dest.** (oder 0,5 ml Extrakt und 3,5ml H2O) in ein kleines Becherglas (25ml) einwiegen und mit einem Glasstab gut verrühren.

2. **0,36g Agar + 5ml H2Odest.** in ein kleines Becherglas (25ml) einwiegen und gut verrühren.

3. Ein ca 20 x 20 cm großes Stück Backpapier auf der Arbeitsfläche vorbereiten, ein 10 x 10 cm großes Stück schwarzes Fliegennetz darauf und ein zweites 20 x 20 großes Backpapierstück und eine stabile Platte zum plattdrücken danebenlegen. (Denn wenn der Agar erstmal in der Algen/Extrakt /Wassermischung ist, muss alles sehr schnell gehen, weil er beim Abkühlen aushärtet).

4. 2. in der Mikrowelle bei 800 Watt schäumend aufkochen und zu 1. dazugeben, sofort mit einem Glasstab verrühren, auf das vorbereitete Fliegennetz überführen, zweites Backpapier darauf und sofort möglichst plattdrücken.

5. Auskühlen lassen und daraus n Stücke a 12 x 12 Fliegennetz-Kästchen ausschneiden. (n=Anzahl der gewünschten Peplikate) Zur Kennzeichnung der Kontroll-Pellets z.B eine Ecke abschneiden.

a. Appendix *Idotea* spp.

Appendix 2 Raw data *Idotea* spp. part 1
Data of the organisms of *Idotea* spp. (Species: 1= *I.balthica*, 2= *I.granulosa*)

Basin	Temp. [°C]	Ind.	Species	Length [mm]	Dry weight [mg]	Faeces [mg]	Pellet [# empty squares]
A-5	5	A.1	1	18	30.910	9.850	2
		A.2	1	20	37.340	8.150	8
		A.3	1	11	9.550	5.500	0
		A.4	2	12	14.770	4.420	0
		A.5	1	12	10.720	7.270	1
		A.6	1	10	7.620	7.430	2
B-10	10	B.1	1	18	32.670	14.820	69
		B.2	1	14	12.650	3.720	0
		B.3	2	11	13.040	9.900	18
		B.4	2	10	9.660	4.500	4
		B.5	2	12	14.200	0.000	2
		B.6	1	11	7.280	10.260	0
C-12	12	C.1	1	15	24.540	21.490	50
		C.2	1	21	43.640	21.550	58
		C.3	1	11	10.840	9.330	2
		C.4	1	13	16.300	11.410	12
		C.5	2	13	22.000	10.420	1
		C.6	1	11	9.130	9.420	0
D-15	15	D.1	1	13	13.340	20.070	25
		D.2	1	14	18.930	22.700	46
		D.3	1	13	20.470	20.640	22
		D.4	1	13	18.180	20.510	98
		D.5	1	12	15.050	18.890	3
		D.6	1	11	9.900	12.960	0
E-20	20	E.1	1	18	31.790	27.240	5
		E.2	1	14	17.850	23.640	19
		E.3	2	13	23.010	10.070	8
		E.4	2	11	16.450	10.170	4
		E.5	1	12	10.550	10.050	6
		E.6	1	11	10.860	19.700	16
F-24	24	F.3	1	13	17.630	19.460	20
		F.4	2	11	13.330	10.950	7
		F.5	1	13	23.550	23.570	19
		F.6	1	10	9.460	11.230	31
G-25	25	G.1	1	14	19.150	10.330	9
		G.2	1	15	21.100	17.220	23
		G.3	2	10	9.860	21.680	1
		G.4	1	14	13.470	20.280	107

		G.5	1	16	22.410	4.870	57
		G.6	1	11	12.890	19.770	50
H-26	26	H.1	1	14	22.150	18.480	45
		H.2	1	14	20.980	22.190	56
		H.3	1	12	19.700	16.590	26
		H.4	2	12	18.920	9.890	6
		H.5	1	12	16.940	15.130	3
		H.6	1	10	7.780	9.570	9
I-27	27	I.1	1	18	39.710	19.860	121
		I.2	1	18	34.920	20.600	34
		I.4	1	11	11.040	13.190	7
		I.5	1	13	14.450	17.060	4
		I.6	1	10	13.850	14.950	5
K-28	28	K.3	1	11	13.730	13.570	11
		K.5	1	13	18.770	7.560	41
		K.6	1	10	9.090	14.200	1
L-29	29	L.2	1	14	16.950	8.020	2
		L.3	1	10	9.410	6.420	0
		L.4		13	20.050	19.220	26
		L.6	1	10	13.010	10.630	6
M-30	30	M.1	1	13	20.740	7.890	4
		M.3	1	14	20.270	8.160	10
		M.4	1	15	20.340	8.270	0
		M.5	1	11	9.570	5.850	3
		M.6	1	10	9.320	8.590	5
T0-C-12	12	C.1	1	15	24.540	10.510	8
		C.2	1	21	43.640	12.550	39
		C.3	1	11	10.840	9.600	8
		C.4	1	13	16.300	13.970	21
		C.5	2	13	22.000	5.780	2
		C.6	1	11	9.130	10.660	11

Appendix 3 Raw data *Idotea* spp. part 2

Faeces and empty squares standardised by the length and the dry weight

Basin	Ind.	Faeces/mm [mg]	Squares/mm	Faeces/mg [mg]	Squares/mg
A-5	A.1	0.547	0.11	0.319	0.06
	A.2	0.408	0.40	0.218	0.21
	A.3	0.500	0.00	0.576	0.00
	A.4	0.368	0.00	0.299	0.00
	A.5	0.606	0.08	0.678	0.09
	A.6	0.743	0.20	0.975	0.26
	MV	**0.529**	**0.13**	**0.511**	**0.11**
B-10	B.1	0.823	3.83	0.454	2.11
	B.2	0.266	0.00	0.294	0.00
	B.3	0.900	1.64	0.759	1.38
	B.4	0.450	0.40	0.466	0.41
	B.5	0.000	0.17	0.000	0.02
	B.6	0.933	0.00	1.409	0.00
	MV	**0.562**	**1.01**	**0.564**	**0.65**
C-12	C.1	1.433	3.33	0.876	2.04
	C.2	1.026	2.76	0.494	1.33
	C.3	0.848	0.18	0.861	0.18
	C.4	0.878	0.92	0.700	0.74
	C.5	0.802	0.08	0.474	0.05
	C.6	0.856	0.00	1.032	0.00
	MV	**0.974**	**1.21**	**0.739**	**0.72**
D-15	D.1	1.544	1.92	1.504	1.87
	D.2	1.621	3.29	1.199	2.43
	D.3	1.588	1.69	1.008	1.07
	D.4	1.578	7.54	1.128	5.39
	D.5	1.574	0.25	1.255	0.20
	D.6	1.178	0.00	1.309	0.00
	MV	**1.514**	**2.45**	**1.234**	**1.83**
E-20	E.1	1.513	0.28	0.857	0.16
	E.2	1.689	1.36	1.324	1.06
	E.3	0.775	0.62	0.438	0.35
	E.4	0.925	0.36	0.618	0.24
	E.5	0.838	0.50	0.953	0.57
	E.6	1.791	1.45	1.814	1.47
	MV	**1.255**	**0.76**	**1.001**	**0.64**
F-24	F.3	1.497	1.54	1.104	1.13
	F.4	0.995	0.64	0.821	0.53
	F.5	1.813	1.46	1.001	0.81
	F.6	1.123	3.10	1.187	3.28
	MV	**1.357**	**1.68**	**1.028**	**1.44**
G-25	G.1	0.738	0.64	0.539	0.47
	G.2	1.148	1.53	0.816	1.09

	G.3	2.168	0.10	2.199	0.10
	G.4	1.449	7.64	1.506	7.94
	G.5	0.304	3.56	0.217	2.54
	G.6	1.797	4.55	1.534	3.88
	MV	**1.267**	**3.00**	**1.135**	**2.67**
H-26	H.1	1.320	3.21	0.834	2.03
	H.2	1.585	4.00	1.058	2.67
	H.3	1.383	2.17	0.842	1.32
	H.4	0.824	0.50	0.523	0.32
	H.5	1.261	0.25	0.893	0.18
	H.6	0.957	0.90	1.230	1.16
	MV	**1.222**	**1.84**	**0.897**	**1.28**
I-27	I.1	1.103	6.72	0.500	3.05
	I.2	1.144	1.89	0.590	0.97
	I.4	1.199	0.64	1.195	0.63
	I.5	1.312	0.31	1.181	0.28
	I.6	1.495	0.50	1.079	0.36
	MV	**1.251**	**2.01**	**0.909**	**1.06**
K-28	K.3	1.234	1.00	0.988	0.80
	K.5	0.582	3.15	0.403	2.18
	K.6	1.420	0.10	1.562	0.11
	MV	**1.078**	**1.42**	**0.984**	**1.03**
L-29	L.2	0.573	0.14	0.473	0.12
	L.3	0.642	0.00	0.682	0.00
	L.4	1.478	2.00	0.959	1.30
	L.6	1.063	0.60	0.817	0.46
	MV	**0.939**	**0.69**	**0.733**	**0.47**
M-30	M.1	0.607	0.31	0.380	0.19
	M.3	0.583	0.71	0.403	0.49
	M.4	0.551	0.00	0.407	0.00
	M.5	0.532	0.27	0.611	0.31
	M.6	0.859	0.50	0.922	0.54
	MV	**0.626**	**0.36**	**0.545**	**0.31**
T0-C-12	C.1	0.701	0.53	0.428	0.33
	C.2	0.598	1.86	0.288	0.89
	C.3	0.873	0.73	0.886	0.74
	C.4	1.075	1.62	0.857	1.29
	C.5	0.445	0.15	0.263	0.09
	C.6	0.969	1.00	1.168	1.20
	MV	**0.777**	**0.98**	**0.648**	**0.76**

Appendix 4 Faeces production *Idotea* spp.; output of SPSS

Analyses of SPSS analyses for the data of *Idotea* spp.

Deskriptive Statistik

	H	Mittelwert	Standard-abweichung	Standard-fehler	95 % Konfidenzintervall für Mittelwert		Minimum	Maximum
					Untergrenze	Obergrenze		
5°C	6	.5287	.13671	.05581	.3852	.6721	.37	.74
10°C	6	.5620	.38367	.15663	.1594	.9646	0.00	.93
12°C	6	.9738	.23748	.09695	.7246	1.2231	.80	1.43
15°C	6	1.5138	.16638	.06793	1.3392	1.6884	1.18	1.62
20°C	6	1.2552	.45944	.18756	.7730	1.7373	.78	1.79
24°C	4	1.3570	.37119	.18559	.7664	1.9476	1.00	1.81
25°C	6	1.2673	.68516	.27971	.5483	1.9864	.30	2.17
26°C	6	1.2217	.28194	.11510	.9258	1.5175	.82	1.59
27°C	5	1.2506	.15757	.07047	1.0550	1.4462	1.10	1.50
28°C	3	1.0787	.44007	.25407	-.0145	2.1718	.58	1.42
29°C	4	.9390	.41955	.20977	.2714	1.6066	.57	1.48
30°C	5	.6264	.13319	.05956	.4610	.7918	.53	.86
Gesamt-summe	63	1.0435	.46091	.05807	.9274	1.1596	0.00	2.17

Zuverlässige Tests auf Gleichheit der Mittelwerte

	Statistik[a]	df1	df2	Sig.
Welch	12.888	11	17.993	.000
Brown-Forsythe	4.627	11	25.457	.001

a. Asymptotisch F-verteilt.

Mehrfachvergleiche

Scheffé

(I) Versuchbedingung		Mittelwert-differenz (I-J)	Standard-fehler	Sig.	95 % Konfidenzintervall	
					Untergrenze	Obergrenze
5°C	10°C	-.03333	.20689	1.000	-.9994	.9327
	12°C	-.44517	.20689	.940	-1.4112	.5209
	15°C	-,98517*	.20689	.041	-1.9512	-.0191
	20°C	-.72650	.20689	.365	-1.6925	.2395
	24°C	-.82833	.23131	.334	-1.9084	.2517
	25°C	-.73867	.20689	.338	-1.7047	.2274
	26°C	-.69300	.20689	.443	-1.6590	.2730
	27°C	-.72193	.21699	.454	-1.7351	.2913
	28°C	-.55000	.25339	.936	-1.7331	.6331
	29°C	-.41033	.23131	.986	-1.4904	.6697
	30°C	-.09773	.21699	1.000	-1.1109	.9155

10°C	5°C	.03333	.20689	1.000	-.9327	.9994
	12°C	-.41183	.20689	.966	-1.3779	.5542
	15°C	-.95183	.20689	.058	-1.9179	.0142
	20°C	-.69317	.20689	.443	-1.6592	.2729
	24°C	-.79500	.23131	.400	-1.8751	.2851
	25°C	-.70533	.20689	.414	-1.6714	.2607
	26°C	-.65967	.20689	.525	-1.6257	.3064
	27°C	-.68860	.21699	.533	-1.7018	.3246
	28°C	-.51667	.25339	.959	-1.6998	.6665
	29°C	-.37700	.23131	.993	-1.4571	.7031
	30°C	-.06440	.21699	1.000	-1.0776	.9488
12°C	5°C	.44517	.20689	.940	-.5209	1.4112
	10°C	.41183	.20689	.966	-.5542	1.3779
	15°C	-.54000	.20689	.804	-1.5060	.4260
	20°C	-.28133	.20689	.999	-1.2474	.6847
	24°C	-.38317	.23131	.992	-1.4632	.6969
	25°C	-.29350	.20689	.998	-1.2595	.6725
	26°C	-.24783	.20689	1.000	-1.2139	.7182
	27°C	-.27677	.21699	.999	-1.2900	.7364
	28°C	-.10483	.25339	1.000	-1.2880	1.0783
	29°C	.03483	.23131	1.000	-1.0452	1.1149
	30°C	.34743	.21699	.994	-.6658	1.3606
15°C	5°C	,98517*	.20689	.041	.0191	1.9512
	10°C	.95183	.20689	.058	-.0142	1.9179
	12°C	.54000	.20689	.804	-.4260	1.5060
	20°C	.25867	.20689	.999	-.7074	1.2247
	24°C	.15683	.23131	1.000	-.9232	1.2369
	25°C	.24650	.20689	1.000	-.7195	1.2125
	26°C	.29217	.20689	.998	-.6739	1.2582
	27°C	.26323	.21699	1.000	-.7500	1.2764
	28°C	.43517	.25339	.989	-.7480	1.6183
	29°C	.57483	.23131	.851	-.5052	1.6549
	30°C	.88743	.21699	.153	-.1258	1.9006
20°C	5°C	.72650	.20689	.365	-.2395	1.6925
	10°C	.69317	.20689	.443	-.2729	1.6592
	12°C	.28133	.20689	.999	-.6847	1.2474
	15°C	-.25867	.20689	.999	-1.2247	.7074
	24°C	-.10183	.23131	1.000	-1.1819	.9782
	25°C	-.01217	.20689	1.000	-.9782	.9539
	26°C	.03350	.20689	1.000	-.9325	.9995
	27°C	.00457	.21699	1.000	-1.0086	1.0178
	28°C	.17650	.25339	1.000	-1.0066	1.3596
	29°C	.31617	.23131	.999	-.7639	1.3962
	30°C	.62877	.21699	.674	-.3844	1.6420

24°C	5°C	.82833	.23131	.334	-.2517	1.9084
	10°C	.79500	.23131	.400	-.2851	1.8751
	12°C	.38317	.23131	.992	-.6969	1.4632
	15°C	-.15683	.23131	1.000	-1.2369	.9232
	20°C	.10183	.23131	1.000	-.9782	1.1819
	25°C	.08967	.23131	1.000	-.9904	1.1697
	26°C	.13533	.23131	1.000	-.9447	1.2154
	27°C	.10640	.24038	1.000	-1.0160	1.2288
	28°C	.27833	.27369	1.000	-.9996	1.5563
	29°C	.41800	.25339	.992	-.7651	1.6011
	30°C	.73060	.24038	.602	-.3918	1.8530
25°C	5°C	.73867	.20689	.338	-.2274	1.7047
	10°C	.70533	.20689	.414	-.2607	1.6714
	12°C	.29350	.20689	.998	-.6725	1.2595
	15°C	-.24650	.20689	1.000	-1.2125	.7195
	20°C	.01217	.20689	1.000	-.9539	.9782
	24°C	-.08967	.23131	1.000	-1.1697	.9904
	26°C	.04567	.20689	1.000	-.9204	1.0117
	27°C	.01673	.21699	1.000	-.9965	1.0299
	28°C	.18867	.25339	1.000	-.9945	1.3718
	29°C	.32833	.23131	.998	-.7517	1.4084
	30°C	.64093	.21699	.646	-.3723	1.6541
26°C	5°C	.69300	.20689	.443	-.2730	1.6590
	10°C	.65967	.20689	.525	-.3064	1.6257
	12°C	.24783	.20689	1.000	-.7182	1.2139
	15°C	-.29217	.20689	.998	-1.2582	.6739
	20°C	-.03350	.20689	1.000	-.9995	.9325
	24°C	-.13533	.23131	1.000	-1.2154	.9447
	25°C	-.04567	.20689	1.000	-1.0117	.9204
	27°C	-.02893	.21699	1.000	-1.0421	.9843
	28°C	.14300	.25339	1.000	-1.0401	1.3261
	29°C	.28267	.23131	.999	-.7974	1.3627
	30°C	.59527	.21699	.747	-.4179	1.6085
27°C	5°C	.72193	.21699	.454	-.2913	1.7351
	10°C	.68860	.21699	.533	-.3246	1.7018
	12°C	.27677	.21699	.999	-.7364	1.2900
	15°C	-.26323	.21699	1.000	-1.2764	.7500
	20°C	-.00457	.21699	1.000	-1.0178	1.0086
	24°C	-.10640	.24038	1.000	-1.2288	1.0160
	25°C	-.01673	.21699	1.000	-1.0299	.9965
	26°C	.02893	.21699	1.000	-.9843	1.0421
	28°C	.17193	.26170	1.000	-1.0500	1.3939
	29°C	.31160	.24038	.999	-.8108	1.4340
	30°C	.62420	.22664	.742	-.4340	1.6824

28°C	5°C	.55000	.25339	.936	-.6331	1.7331
	10°C	.51667	.25339	.959	-.6665	1.6998
	12°C	.10483	.25339	1.000	-1.0783	1.2880
	15°C	-.43517	.25339	.989	-1.6183	.7480
	20°C	-.17650	.25339	1.000	-1.3596	1.0066
	24°C	-.27833	.27369	1.000	-1.5563	.9996
	25°C	-.18867	.25339	1.000	-1.3718	.9945
	26°C	-.14300	.25339	1.000	-1.3261	1.0401
	27°C	-.17193	.26170	1.000	-1.3939	1.0500
	29°C	.13967	.27369	1.000	-1.1383	1.4176
	30°C	.45227	.26170	.989	-.7697	1.6742
29°C	5°C	.41033	.23131	.986	-.6697	1.4904
	10°C	.37700	.23131	.993	-.7031	1.4571
	12°C	-.03483	.23131	1.000	-1.1149	1.0452
	15°C	-.57483	.23131	.851	-1.6549	.5052
	20°C	-.31617	.23131	.999	-1.3962	.7639
	24°C	-.41800	.25339	.992	-1.6011	.7651
	25°C	-.32833	.23131	.998	-1.4084	.7517
	26°C	-.28267	.23131	.999	-1.3627	.7974
	27°C	-.31160	.24038	.999	-1.4340	.8108
	28°C	-.13967	.27369	1.000	-1.4176	1.1383
	30°C	.31260	.24038	.999	-.8098	1.4350
30°C	5°C	.09773	.21699	1.000	-.9155	1.1109
	10°C	.06440	.21699	1.000	-.9488	1.0776
	12°C	-.34743	.21699	.994	-1.3606	.6658
	15°C	-.88743	.21699	.153	-1.9006	.1258
	20°C	-.62877	.21699	.674	-1.6420	.3844
	24°C	-.73060	.24038	.602	-1.8530	.3918
	25°C	-.64093	.21699	.646	-1.6541	.3723
	26°C	-.59527	.21699	.747	-1.6085	.4179
	27°C	-.62420	.22664	.742	-1.6824	.4340
	28°C	-.45227	.26170	.989	-1.6742	.7697
	29°C	-.31260	.24038	.999	-1.4350	.8098

*. die Mittelwertdifferenz ist auf der Stufe 0.05 signifikant.

Appendix 5 T-Test *Idotea* spp., output of SPSS

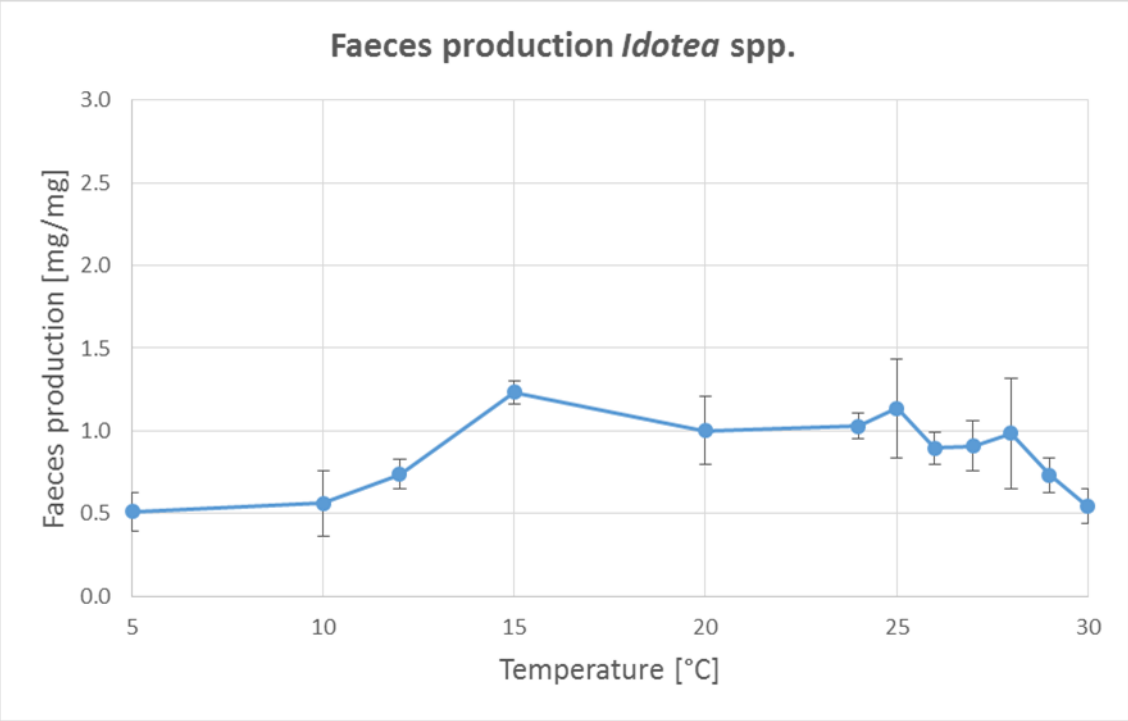
T-test on the influence of the experimental design; faeces quantity tested at beginning and end of the keeping

Statistik für Stichproben mit paarigen Werten

		Mittelwert	H	Standard-abweichung	Standardfehler Mittelwert
Paar 1	Anfangs-Kotmenge[mg]	.9738	6	.23748	.09695
	End-Kotmenge[mg]	.7768	6	.23788	.09711

Korrelationen für Stichproben mit paarigen Werten

		H	Korrelation	Sig.
Paar 1	Anfangs-Kotmenge[mg] & End-Kotmenge[mg]	6	-.179	.735



Appendix 6 Faeces production *Idotea* spp.; dry weight

Mean faeces production per experimental basin at different temperatures. Standardised by dry weight of the organisms.

b. Appendix *Gammarus* spp.

Appendix 7 Raw data *Gammarus* spp. part 1
Data of the organisms of *Idotea* spp. (Species: 0= undefined, 1= *G.locusta*, 2= *G.oceanicus*, 3= *G.salinus*)

Basin	Temp. [°C]	Ind.	Species	Length [mm]	Dry weight [mg]	Faeces [mg]	Pellet [# empty squares]
A-5	5	A.1	0	10	5.420	0.000	0
		A.3	2	27	62.260	19.340	17
		A.4	2	19	20.190	5.720	0
		A.5	1	13	7.850	4.140	0
B-10	10	B.1	2	25	39.660	10.080	4
		B.2	2	21	40.080	9.500	8
		B.3	2	22	33.110	15.820	14
		B.4	2	18	20.250	12.980	1
C-12	12	C.2	2	24	43.130	10.410	6
		C.3	2	25	47.870	12.110	14
		C.4	2	19	21.450	18.460	14
		C.5	1	16	10.320	7.400	1
D-15	15	D.1	2	24	43.880	21.720	89
		D.2	2	27	58.390	7.950	1
		D.3	2	19	17.630	8.210	0
		D.4	1	18	16.610	13.860	7
		D.5	3	14	9.540	9.920	2
E-20	20	E.1	2	23	43.670	8.400	0
		E.2	2	24	34.770	19.280	74
		E.3	1	18	12.700	12.060	6
		E.4	2	17	19.420	17.100	41
		E.5	1	15	11.840	17.490	19
		E.6	1	11	5.930	10.740	6
F-24	24	F.2	2	22	33.600	6.520	1
		F.5	1	14	6.950	9.570	0
G-25	25	G.1	2	27	46.360	5.850	0
		G.2	1	21	23.730	11.540	29
		G.3	2	18	16.540	5.850	1
		G.4	2	19	20.540	8.240	8
		G.5	1	13	5.960	9.170	2
H-26	26	H.2	2	26	45.290	10.810	4
I-27	27	I.2	2	23	31.090	7.640	0
T0-C-12	12	C.2	2	24	43.130	8.320	4
		C.3	2	25	47.870	11.060	2
		C.4	2	19	21.450	9.550	7
		C.5	1	16	10.320	7.630	4

Appendix 8 Raw data of *Gammarus* spp. part 2

Faeces and empty squares standardised by the length and the dry weight

Basin	Ind.	Faeces/mm [mg]	Squares/mm	Faeces/mg [mg]	Squares/mg
A-5	A.1	0.000	0.00	0.000	0.00
	A.3	0.716	0.63	0.311	0.27
	A.4	0.301	0.00	0.283	0.00
	A.5	0.318	0.00	0.527	0.00
	MV	**0.334**	**0.16**	**0.280**	**0.07**
B-10	B.1	0.403	0.16	0.254	0.10
	B.2	0.452	0.38	0.237	0.20
	B.3	0.719	0.64	0.478	0.42
	B.4	0.721	0.06	0.641	0.05
	MV	**0.574**	**0.31**	**0.402**	**0.19**
C-12	C.2	0.434	0.25	0.241	0.14
	C.3	0.484	0.56	0.253	0.29
	C.4	0.972	0.74	0.861	0.65
	C.5	0.463	0.06	0.717	0.10
	MV	**0.588**	**0.40**	**0.518**	**0.30**
D-15	D.1	0.905	3.71	0.495	2.03
	D.2	0.294	0.04	0.136	0.02
	D.3	0.432	0.00	0.466	0.00
	D.4	0.770	0.39	0.834	0.42
	D.5	0.709	0.14	1.040	0.21
	MV	**0.622**	**0.86**	**0.594**	**0.54**
E-20	E.1	0.365	0.00	0.192	0.00
	E.2	0.803	3.08	0.555	2.13
	E.3	0.670	0.33	0.950	0.47
	E.4	1.006	2.41	0.881	2.11
	E.5	1.166	1.27	1.477	1.60
	E.6	0.976	0.55	1.811	1.01
	MV	**0.831**	**1.27**	**0.978**	**1.22**
F-24	F.2	0.296	0.05	0.194	0.03
	F.5	0.684	0.00	1.377	0.00
	MV	**0.490**	**0.02**	**0.786**	**0.01**
G-25	G.1	0.217	0.00	0.126	0.00
	G.2	0.550	1.38	0.486	1.22
	G.3	0.325	0.06	0.354	0.06
	G.4	0.434	0.42	0.401	0.39
	G.5	0.705	0.15	1.539	0.34
	MV	**0.446**	**0.40**	**0.581**	**0.40**
H-26	H.2	0.416	0.15	0.239	0.09
I-27	I.2	0.332	0.00	0.246	0.00
T0-C-12	C.2	0.347	0.17	0.193	0.09

	C.3	0.442	0.08	0.231	0.04
	C.4	0.503	0.37	0.445	0.33
	C.5	0.477	0.25	0.739	0.39
	MV	**0.442**	**0.22**	**0.402**	**0.21**

Appendix 9 Faeces production *Gammarus* spp., output of SPSS

Analyses of SPSS analyses for the data of *Gammarus* spp.

Deskriptive Statistik

	H	Mittelwert	Standard-abweichung	Standard-fehler	Mittelwert		Minimum	Maximum
					Untergrenze	Obergrenze		
5°C	4	.3338	.29373	.14686	-.1336	.8011	0.00	.72
10°C	4	.5738	.17006	.08503	.3032	.8443	.40	.72
12°C	4	.5883	.25665	.12833	.1799	.9966	.43	.97
15°C	5	.6220	.25162	.11253	.3096	.9344	.29	.91
20°C	6	.8310	.28556	.11658	.5313	1.1307	.37	1.17
24°C	2	.4900	.27436	.19400	-1.9750	2.9550	.30	.68
25°C	5	.4462	.19047	.08518	.2097	.6827	.22	.71
26°C	1	.4160					.42	.42
27°C	1	.3320					.33	.33
Gesamt-summe	32	.5637	.26881	.04752	.4668	.6606	0.00	1.17

Varianzhomogenitätstest

Levene-Statistik	df1	df2	Sig.
,248[a]	6	23	.955

a. Gruppen mit nur einem Fall werden bei der Berechnung des Varianzhomogenitätstests für

ANOVA

	Quadrat-summe	df	Mittel der Quadrate	F	Sig.
Zwischen Gruppen	.815	8	.102	1.646	.166
Innerhalb der Gruppen	1.425	23	.062		
Gesamtsumme	2.240	31			

Appendix 10 T-test *Gammarus* spp.; output of SPSS

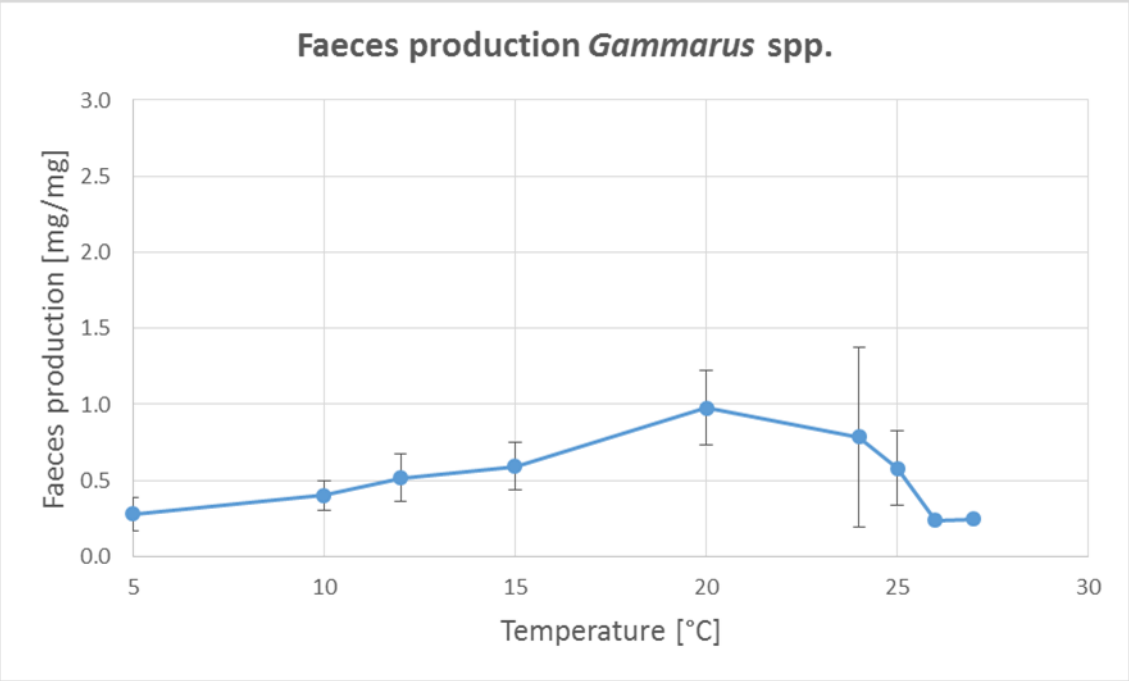
T-test on the influence of the experimental design; faeces quantity tested at beginning and end of the keeping

Statistik für Stichproben mit paarigen Werten

		Mittelwert	H	Standard-abweichung	Standardfehler Mittelwert
Paar 1	Anfangs-Kotmenge[mg]	.5883	4	.25665	.12833
	End-Kotmenge[mg]	.4423	4	.06824	.03412

Korrelationen für Stichproben mit paarigen Werten

		H	Korrelation	Sig.
Paar 1	Anfangs-Kotmenge[mg] & End-Kotmenge[mg]	4	.641	.359



Appendix 11 Faeces production *Gammarus* spp.; dry weight

Mean faeces production per experimental basin at different temperatures. Standardised by dry weight of the organisms

VI. Literature

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VII. Acknowledgements

First of all I would like to thank Prof. Dr. Martin Wahl, who supervised this thesis and gave me the opportunity to do my research within the Benthic Ecology of the GEOMAR.

For his willingness to support this thesis from the University of Oldenburg as an external thesis, I want to thank Prof. Dr. Pedro Martínez Arbizu.

Furthermore, I would like to thank Stefanie Raddatz, Dr. habil. Florian Weinberger and Nadja Stärck who always answered all the open questions I had at the beginning or during my research.

I would also like to thank Patrick Blaß, who waded with me through the *Fucus* in Bülk to catch all the organisms I needed for my experiments and thereby proved his tolerance to very cold water temperatures.

Vor allem- und das nun auf deutsch- möchte ich meiner Familie und meinen Freunden danken. Danke, dass ihr immer für mich da ward und mich all die Jahre unterstützt habt, meinem Traum ein Stück näher zu kommen. WIR haben's geschafft!

Erklärung

Hiermit versichere ich, dass ich diese Arbeit selbstständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe. Außerdem versichere ich, dass ich die allgemeinen Prinzipien wissenschaftlicher Arbeit und Veröffentlichung, wie sie in den Leitlinien guter wissenschaftlicher Praxis der Carl von Ossietzky Universität Oldenburg festgelegt sind, befolgt habe.

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